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ANALYSES OF WEIGHT, BODY-FAT, AND PHYSICAL FITNESS TESTING STANDARDS, FOR ACTIVE DUTY MALE MARINES, WITH PROPOSED ALTERNATIVES

by

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The Marine Corps utilizes a three-event Physical Fitness Test (PFT) comprised of a 3-mile run, sit-ups, and pull-ups to assess the level of physical fitness of individual Marines. This thesis uses newly collected data from the Marine Corps to analyze the current weight and body-fat standards and compare them with proposed alternatives. The research investigates whether the current standards can be slightly relaxed without resulting in significant decreases in physical fitness performance. Additionally, this thesis investigates the validity of pull-ups as an indicator of muscular strength and endurance. The analysis compares the performance scores for two types of pull-ups (the dead-hang and kip methods) with other physical performance events which require upper body strength and muscular endurance. The thesis also presents proposed scoring alternatives for the pull-up event based on an analytical comparison of performance distributions for the run and sit-up events, in order to level the equality for all three PFT events. Additionally, a new 3-profile PFT alternative comprised of aerobic, muscular, and body-fat profiles is presented as an improved measure of assessing the physical fitness of individual Marines.

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ABSTRACT

The Marine Corps utilizes a three-event Physical Fitness Test (PFT) comprised of a 3-mile run, sit-ups, and pull-ups to assess the level of physical fitness of individual Marines. This thesis uses newly collected data from the Marine Corps to analyze the current weight and body-fat standards and compare them with proposed alternatives. The research investigates whether the current standards can be slightly relaxed without resulting in significant decreases in physical fitness performance. Additionally, this thesis investigates the validity of pull-ups as an indicator of muscular strength and endurance. The analysis compares the performance scores for two types of pull-ups (the dead-hang and kip methods) with other physical performance events which require upper body strength and muscular endurance. The thesis also presents proposed scoring alternatives for the pull-up event based on an analytical comparison of performance distributions for the run and sit-up events, in order to level the equality for all three PFT events. Additionally, a new 3-profile PFT alternative comprised of aerobic, muscular, and body-fat profiles is presented as an improved measure of assessing the physical fitness of individual Marines.

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EXECUTIVE SUMMARY

Maintaining desirable body composition and physical fitness is an integral requirement for Marines to perform their mission successfully, maintain combat effectiveness, be competitive for promotions and maintain career advancement. The Marine Corps uses a three-event Physical Fitness Test (PFT) comprised of a 3-mile run, sit-ups, and pull-ups to assess physical fitness levels. During the required semi-annual PFT, individuals are weighed and measured as a screening tool to identify overweight and/or over-fat Marines. The National Center for Health Statistics (NCHS) classifies males as overweight if they exceed the 85th percentile of body mass for the 20-29 year old age group of their gender. Scientific research has demonstrated that excess body-fat adversely affects physical performance (Peterson, Cronan, & Conway, 1987). The maximum 18 percent body-fat limit required by the Marine Corps may need adjustment given that the new body-fat tables have a standard error of plus or minus 3.2 percent body-fat (Hodgdon, 1997). It is proposed that the maximum allowable percentage of body-fat should be established at the respective percentage in which physical performance is significantly hampered.

The recent implementation of the stricter dead-hang pull-ups is controversial as a valid measure of upper-body strength and endurance. Several studies have found that body weight is a major confounder in the performance of pull-ups, indicating that extra mass in the form of fat or large muscle mass is disadvantageous (Pate, Ross, Baumgartner, & Sparks, 1983; Cotton, 1990).

The purpose of this study is to investigate Marine Corps' fitness regulations to examine whether relaxing the maximum weight and/or percent body-fat standards can

be justified without resulting in significant decreases in physical fitness. In addition, the study will investigate whether dead-hang pull-ups are a valid test of physical strength and muscular endurance based on body size. Additional analysis will determine whether the scored performance distribution for pull-ups is 'equitable' in comparison with the scored performance distributions for the run and sit-up events.

Three major sets of data were collected to allow a thorough analysis of the issues of weight, body-fat, and physical fitness. Data set 1 included 223 subjects from 78 different major MOSs ranging in age from 18-43. All participants were individually measured for body-fat, and PFT results were collected from old and new test standards. Data set 2 includes the recorded PFT scores for 430 subjects gathered from six representative command organizations. These subjects were also from 78 different major MOSs and ranged in age from 18-42. Included in this set are 312 PFT scores recorded using the old pull-up standards. Data set 3 contains the records of 200 male officer candidates ranging in age from 21-32. The data provides recorded scores for such physical fitness events as the PFT (3-mile run, sit-ups, pull-ups), obstacle, endurance, and combat conditioning courses, as well as body-fat measurements.

This study analyzed and compared the current weight and body-fat standards with the respective NCHS proposed weight alternative and a 20 percent body-fat alternative, and determined that the relaxation of weight limits to these standards does not indicate any significant decrease in physical fitness performance (p-value < 0.05). Therefore the Marine Corps could increase its maximum weight requirements (approximately two additional pounds at each respective height) to match the NCHS standards and still maintain current levels of physical fitness. With the development of more sophisticated technologies the new Marine Corps body-fat tables are designed to provide an improvement over the old tables, and to give a more accurate assessment of body-fat for individual Marines. However, the current data indicate an alarming 23 percent of Marines may exceed the 18 percent body-fat standard, with the majority of those individuals actually being within their respective weight limits, and almost half of them being qualified with first class PFT scores. Relaxing the current body-fat maximum of 18 percent to 20 percent would result in only 11.2 percent of Marines exceeding the new limit, and would not result in a significant decrease in physical performance. Marines with 19 and 20 percent body-fat perform just as well on the PFT as Marines within the 18 percent limit. This apparent relaxation of standards will allow the Marine Corps to maintain the prestige of having the strictest body-fat standards of all the services in the United States Armed Forces.

This study also compared the performance scores for two types of pull-ups (the new dead-hang and old kip methods) with other performance events requiring upper body strength and muscular endurance. The results indicate that pull-ups are not necessarily a strong predictor of overall upper body muscular strength and endurance. The results of this study validate the findings of other studies that body weight is a major confounder in the performance of pull-ups, indicating that extra mass in the form of fat or large muscle mass is disadvantageous. Additionally, this report presents proposed scoring alternatives for the pull-ups based on an analytical comparison of performance distributions with the run and sit-up events, in order to level the equality of the three PFT events. The proposed alternative suggests scaling the value of the first ten pull-ups with greater weight than the last ten pull-ups so that the mean score of 12.8 pull-ups rates a score of about 75 points. This scaling of scores for pull-ups results in a more equitable comparison of scores with the other PFT events and may provide an improved representation of upper body strength and muscular endurance. The best scoring method for measuring strength and endurance from the pull-up test requires a computation of the 'total work done' as a factor of height, weight and the number of pull-ups conducted.

It is important to distinguish between the terms overweight and over-fat, and understand that our focus should be shifted from looking at how much a Marine weighs to determining how much of his body weight is actually fat. Utilizing the weight-height tables as an initial screening tool positively identifies only 31 percent of all the Marines who are actually overly fat based on the current 18 percent standard. A slightly more accurate initial screening method would require the employment of the body mass index as the weight-height predictor of body-fat. However, the best alternative requires the actual anthropometric measurement of each Marine to assess accurate estimates of body-fat. A Marine's physical ability to perform satisfactorily under prescribed fitness standards should be the underlying factor in assessing the cut-off criteria for acceptable limits in allowable body-fat and weight. Additionally, this study proposes a new 3-profile PFT alternative in an effort to improve upon the Marine Corps' Physical Fitness Program.

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I. INTRODUCTION

A. BACKGROUND

Department of Defense (DoD) policy dictates that physical fitness is essential to the combat readiness of the Armed Forces (DoD 1308.1). Physical fitness provides individuals with cardio-respiratory endurance, muscular strength and endurance, and whole body flexibility, as well as balance, agility, and explosive power. The DoD Physical Fitness and Body-Fat Program requires individual service members to possess the appropriate levels of fitness and body composition to perform successfully in accordance with their service's specific mission and military occupational specialty (MOS). For a Marine this means a healthy body, the endurance to withstand the stress of prolonged activity and adverse environments, the capacity to endure the discomforts that accompany fatigue, and the ability to maintain day-to-day combat effectiveness. This study will investigate Marine Corps fitness regulations to determine whether relaxing the maximum weight and/or percent body-fat standards can be justified without decreasing physical fitness. In addition, the study will analyze whether dead-hang pull-ups are a valid test of physical strength and muscular endurance based on body size, and whether the scored performance distribution for pull-ups is 'equitable' in comparison with the scored performance distributions for the run and sit-up events.

Maintaining desirable body composition is an integral part of physical fitness, general health, and military appearance. The DoD maximum weight limits are specified in a "Height-Weight Screening Table" in DoD Instruction 1308.3, but each service is authorized to institute stricter rules. All personnel are required to meet and maintain both physical fitness and body-fat standards (DoD 1308.1). In implementing body composition programs that enhance general health, physical fitness, and military appearance, departments must ensure that actual weight loss is viewed as less important than the reduction in body-fat (DoD 1308.1). As a result, the Marine Corps has recently shifted focus in the weight control program from height-weight standards to body-fat measurements. The current Marine Corps' height-weight tables as stated in Marine Corps Order (MCO) 6100.10B, "Weight Control and Military Appearance," remain stricter than those prescribed by the current DoD instructions.

The male Marine physical fitness test (PFT) consists of three events: pull-up/chin-up, bent knee sit-ups, and a 3-mile run, and is to be administered at least semiannually. The pull-ups are executed from a dead hang position. One repetition consists of raising the body with both arms until the chin is above the bar and lowering the body until the arms are fully extended again. The bar may be gripped with the palms facing in or out. The pull-ups are no longer conducted with any whipping, kicking or kipping motion allowed, and are repeated as many times as possible before dismounting the bar. The maximum score is attained at 20 repetitions. A certain amount of inherent body movement will occur; however, the intent is to avoid a pendulum-like motion, which deters from the ability to conduct a proper vertical pull-up (dead-hang). The sit-ups are started on the back with shoulder blades touching the deck, knees flexed and both feet flat on the deck. The new modified sit-ups no longer require the hands to be placed behind the head; rather the arms are folded across the chest. Additionally, it is no longer required to break the imaginary plane at the knees. One repetition now consists of raising the upper body until the elbows touch the thighs and then returning to the starting position. As many sit-ups as possible are performed over a two minute time period. The maximum score is attained at 80 repetitions for the old style sit-up, and 100 repetitions for the modified sit-up. The 3-mile course is measured over reasonably level ground, and should be run as quickly as possible. A maximum score is attained in 18 minutes, although the course must be completed in 28, 29, or 30 minutes depending on the Marine's age group.

The PFT events are intended to provide an instrument which measures the level of physical fitness of all Marines by testing the strength and stamina of the upper body, the abdomen, the lower body, and the cardiovascular system. Table 1 lists each PFT event with corresponding scores (the old sit-up scores are listed), which apply to all ages. Each event within the PFT has a maximum score of 100 points for a combined total of 300 points. Table 2 shows the respective classification standards based on minimum acceptable performance. To successfully pass the test, a Marine must obtain the minimum points required for each of the three events, plus earn the required additional points listed by age group in Table 2. In an effort to update policy and implement refined instructions, the Marine Corps has made recent changes to its orders on both "Physical Fitness" and "Weight Control and Military Appearance." The MCOs were revised in order to:

1. Eliminate the alternate weight waiver and establish a body-fat standard for Marines who exceed the height/weight standard (ALMAR 326/97).
2. Revise the guidelines for executing the pull-up from a dead-hang position (ALMAR 070/96, and 213.96).
3. Outline modifications to the sit-ups (ALMAR 369/97).

Current MCOs on weight control and physical fitness require height and weight measurements to be taken in conjunction with the semiannual PFT in order to screen for over-fat Marines. The recent changes to the Performance Evaluation System (MCO P1610.7D) require entries for PFT scores along with height-weight measurements to be included in the fitness reports. If a Marine is recorded as exceeding his maximum weight limit, his percent body-fat estimate is to be assessed

Table 1. The Marine Corps PFT Scoring System.

Points	Pull-ups (repetitions)	Sit-ups (repetitions)	3-mile Run (min:sec)
100	20	80	18:00
90	18	75	19:40
80	16	70	21:20
70	14	65	23:00
60	12	60	24:40
50	10	50	26:20
40	8	40	28:00
30	6	30	29:40
20	4	20	31:20
10	2	10	33:00

Table 2. The Marine Corps Classification of PFT Scores with the Required Minimum Acceptable Performance for each Event based on the Respective Age Groups.

Age	Minimum Pull-up Points	Minimum Sit-up Points	Minimum Run Points	Sub-Total Points	Additional Points Required	Failing Scores	3rd Class Scores	2nd Class Scores	1st Class Scores
17-26	15	50	40	105	30	0-134	135-174	175-224	225-300
27-39	15	45	34	94	16	0-109	110-150	150-199	200-300
40-45	15	45	28	88	0	0- 87	88-124	125-174	175-300
46 +	15	40	10	65	0	0-64	65-99	100-149	150-300

and included in the fitness report with a comment which states 'the Marine is or is not within established standards' (MCO P1610.7D). If both the weight and body-fat recorded in the report exceed the standards, the report is automatically adverse. Marines who are officially assigned to the weight control and military appearance program at any time during the reporting period also warrant an adverse report even if they have been removed from the program or are making significant progress. The now-automatic adverse reporting system is expected to be controversial. Fuentes (Aug 1997) reported that with the implementation of the tougher pull-ups "top Marine Corps officials believe that last year's prediction that PFT scores would drop has come true." Significant decreases in PFT scores will directly impact a Marine's chances for promotion and career enhancement.

If a Marine is deemed underweight or overweight but performs satisfactorily, looks good in uniform, and passes the PFT, the Marine Corps assumes that his body-fat percentage is likely to meet the prescribed standards. However, the standards may need adjustment if it can be convincingly demonstrated that a significant number of Marines who fail the current weight or body-fat standards are in fact healthy, energetic and able to pass the PFT. To ensure that large, healthy, proficient Marines are not inadvertently or unjustly administered adverse remarks or an adverse fitness report, it is important that distinguishable and proper classification of Marines as 'overweight' or 'over-fat' are accurately based on sound scientific reasoning. A Marine's physical ability to perform satisfactorily under the prescribed fitness standards should be the underlying factor for establishing maximum weight and percent body-fat limits.

B. PROBLEM STATEMENT

This study investigates the relationships between selected anthropometric measures and performance on the physical fitness tests. The research conducted for this study reveals controversial issues pertaining to the current Marine Corps' standards for evaluating fitness, which could have unfair effects on larger Marines and on their careers. Indications are that the current weight limits are outdated and obsolete as they pertain to satisfactory physical fitness performance. The semi-annual weigh-ins do not provide the best initial screening measure of fat and fitness for Marines deemed overweight. The current body-fat limit of 18 percent is unnecessarily strict and inaccurate for the purpose of separating substandard performers from satisfactory performers. The pull-up test is confounded by weight, and does not provide the best indication of upper-body strength and muscular endurance for larger Marines. The implementation of the dead-hang pull-up has resulted in controversial effects on the physical fitness test score and evaluation. The dead-hang pull-up produces significantly lower pull-up scores than before, as well as producing much lower scores than either the run or sit-up tests. An increased focus on improving pull-up scores has indirectly resulted in a drop in performance in cardiovascular fitness (run scores), which may not be the intended direction of the Marine Corps' fitness program. Thus, the aim of this study is to examine each of these potential problems in a continuing effort to improve the overall fitness evaluation and testing standards of the Marine Corps so that large, healthy, proficient Marines are not inadvertently or unjustly reprimanded. The overall problem was divided into the following sub-problems:

1. To study the relationships between PFT performance and
    a. body weight (percentile body mass)
    b. percent body-fat
2. To study relationships between pull-up performance and
    a. anthropometric body measures (height, weight, mass, fat)
    b. PFT battery scoring (run, sit-ups)
    c. upper-body strength and muscular endurance field tests

C. SUPPORTING RESEARCH

1. Outdated Weight Requirements

A variety of height-weight tables exist, often subdivided for gender, age, and body build; among the tables used by the military are those originally prepared in

1942 and since improved upon by the Metropolitan Life Insurance Company. The underlying idea was that weights of 20 to 25 year-old persons were 'ideal' and should be maintained throughout life. The validity of these tables can now be questioned based on the variability of anthropometric measures, which indicate that there has been a dramatic increase in adult size of individuals over the past 50 years. Validity of the tables can also be challenged since they were based on the recipients of life insurance, who do not necessarily represent a random sample of the general population. Kroemer (1986) points out that with increasing age, certain dimensions begin to change, heights are reduced, and circumference and weight increase. Data from virtually all major surveys in the U.S. and Europe indicate an increase in average stature of about 1 centimeter per decade. Weight increases were even more dramatic, in the neighborhood of 2-kg (4.4 lbs.) for every ten years (Kroemer, 1986). While the Marine Corps height-weight tables remained stricter than the prescribed DoD directives, Rupinski (Aug. 1989) found that from 1982 through 1987 the proportion of overweight male recruits increased from 9.8 percent to 13.1 percent. The Marine Corps and Navy weight limits do not account for age, yet the Army's weight limits do. Under the National Center for Health Statistics (NCHS) Standards, adults of any age are classified as overweight if they exceed the 85th percentile of body mass for the 20-29 year-old age group of their gender. For example, a commonly used body mass index is defined by the ratio weight/height^2 (kg/m^2). This term is commonly referred to as Quetelet's index. Several studies have found that Quetelet's index is the best weight-height predictor of body-fat in men (Peterson, Cronan, 1987). Table 3 shows that the current Marine Corps maximum weight limits for each height, expressed in terms of percentiles of body mass, are all below the 85th percentile for the same height in the 20-29 year-old age group.

2. Weight–Height Tables as Initial Over-Fat Screening

The Marine Corps currently uses the weight-height table as a preliminary screening tool to identify potentially over-fat Marines. Only those Marines over their respective weight requirements are measured to determine whether they meet or exceed the 18 percent body-fat requirement. One of the problems with using the weight-height tables as the primary screening method in identifying overly fat individuals is that these tables do not discriminate between muscle and fat weight in individuals. They are based on an 'ideal' proportion of weight to height. When people exceed certain cut-off points, it is erroneously assumed that they are the most

Table 3. Current Marine Corps Weight Standards Compared With The Proposed NCHS 85th Percentile Maximum Weight Standards. At All Respective Heights The Marine Corps Standards are Stricter Than the NCHS Standards.

Height (Inches)	Current Maximum Weight Standards In Pounds	Current Max Weight Standards: As Percentile Of Body Mass	NCHS Overweight Standards: 85th Percentile Weight in Pounds
60	140	83	142
61	145	83	147
62	150	84	152
63	155	84	157
64	160	84	162
65	165	84	167
66	170	84	172
67	175	84	177
68	181	84	183
69	186	84	188
70	192	84	194
71	197	84	199
72	203	84	205
73	209	84	211
74	214	84	216
75	219	83	222
76	225	83	228
77	230	83	234
78	235	82	240

likely candidates to be overly fat. However, this assumption can be inaccurate for relatively lean individuals who are especially muscular and therefore weigh more than average people of equivalent height (e.g., football players or body builders).

Conversely, weight-height screening may not identify some individuals who fall within acceptable weight ranges but truly have excess body-fat relative to their lean mass (Peterson, Cronan, & Conway, 1987).

3. Toughest Service Body-Fat Standards

Peterson et al. (1987) demonstrated that excess body-fat adversely affects physical performance. Current Marine Corps orders state that "although there are no readily definable percent fat values for acceptable performance, there are ranges when it can be said that performance will be helped or hampered by body composition" (MCO 6100.10B). On the other hand, the DoD policy states that "service members whose duties require muscular and cardio-respiratory endurance may be hampered in performing their duties when body-fat exceeds 26 percent in males and 36 percent in females" (DoD 1308.1). Current Marine Corps policy provides "tables that are an improvement over the preceding ones in that they were developed using a 4-compartment body composition analysis (fat mass, bone mass, water mass, and residual lean mass) as the basis of equation development, rather than the 2-compartment (fat mass and fat free mass) analysis used previously" (Hodgdon, 1997). Friedl et al. (1992) determined that the four-compartment model approach to percent-body-fat estimation improves upon the two-compartment models in terms of accuracy by accounting for the bone mineral and water components, which are otherwise erroneously assumed to be of fixed proportions.

The Marine Corps, more than any other service, relies on maximum physical fitness of all its personnel. Accordingly, the body-fat maxima remain unchanged at 18 percent for males, and 26 percent for females, regardless of age. These standards greatly exceed DoD prescribed ranges and remain the toughest body-fat requirements of all the services. The Navy, for example, allows men to have up to 22 percent body-fat, and women to have up to 30 percent (and are currently contemplating raising the limit to 33 percent). The Army's maximum allowable percent body-fat standards are based on age as shown in Table 4.

Table 4. Current U.S. Army Body-Fat Standards (AR 600-9).

Age Group	Male (% Body-Fat)	Female (% Body-Fat)
17-20	20	28
21-27	22	30
28-39	24	32
40 & older	26	34

However, all Army personnel are encouraged to achieve the more stringent Department of Defense-wide goal of 20 percent for males and 26 percent for females (AR 600-9).

4. Not as Lean as Expected

While there are several methods available for estimating body-fat, the Marine Corps prefers to use the tape measurement because it is the easiest, most portable and least expensive. In justifying the choice of the tape over other methods of estimating body-fat, Marine officials explain that the caliper method is not preferable because the level of expertise required to use the calipers is far greater than is needed to use the tape measurement, and thus is more likely to contain user error problems. They also indicate that the hydrostatic weighing method is too expensive for practical use. Bioelectrical impedance analysis, which uses the newest technological advancement with laser devices to estimate body-fat, also is too expensive and impractical for wide use by Marines around the world.

To assess an individual's body-fat, the Corps employs a crude field test based on anthropometry, a technique for measuring external parts of the body. All that is needed is a tape measure and the appropriate chart. The new method of estimating body-fat for men is based on height and the girth measurements (circumference) of the neck and waist. The new body-fat percentage is determined by subtracting the neck measurement from the waist measurement and comparing the difference with the height on the body-fat chart (see Appendix B). The old chart only compared the neck and waist measurements and did not account for height. As a result of the development of the new body-fat chart, Hodgdon (1997) suggests that the waist and neck circumferences (for men) used in conjunction with height can provide a valid prediction of percent fat derived from a 4-compartment analysis. On the average, predictions from this new chart do not differ from those obtained using the previous Marine Corps body-fat chart (Hodgdon, 1997). However, feedback received by the authors of the new MCO on physical fitness, from the Training and Education Division (T&E Division), Marine Corps Combat Development Center, indicates there have been exceptions. Several Marine organizations have reported isolated cases of individuals who were previously within standards on the old chart, but are now exceeding the standards with the new chart. Both Dr. Hodgdon and the T&E Division attribute these differences to "the new chart being more accurate and that those Marines showing a higher body-fat are probably not as lean as they had previously believed." Another possibility is that the body-fat estimates may tend to have their greatest variance in the tails of the distribution, i.e., the greatest differences between the two charts are more likely to occur on the extreme high and low ends of the estimated percent body-fat spectrum. Table 5 shows a comparison of selected individuals with their respective body-fat estimates taken from both charts.

Table 5. Isolated Cases for Percent Body-Fat Chart Comparison.

Subject	Weight (lbs.)	Height (in)	Waist (in)	Neck (in)	Percent Body-Fat Old Chart	New Chart
A	173	72	33	15	15	14
B	182	73	35	14.5	20.3	18
C	134	69.5	27	14	6.9	2
D	166	65.5	35.5	16	16.5	19
E	167	67	34.5	15	17.8	19

A Navy Times study in 1993 determined that a number of sailors who failed the body-fat test using the tape (the same test recently adopted by the Marine Corps) could meet the required standard when measured using calipers or hydrostatic weighing (Fuentes, Oct 1997). In none of the cases in the Navy Times study did all three methods come to the same value of percent body-fat. The differences in body-fat estimates shown in Table 5 support a similar comparison. In the case of subjects A through E, the comparison illustrates the differences in isolated cases between the old 2-compartment analysis chart versus the new 4-compartment analysis chart. These cases indicate that the taller subjects (A and B), may fare better with the new chart. Shorter subjects (D and E) who were slightly within standards using the old chart, are now in violation of exceeding the 18 percent limit. Subject C is an isolated example of a case showing a surprisingly large difference between the two methods on the low end of the body-fat spectrum. The reality is that if the new method is in fact more accurate than the old method there is a possibility that even more Marines will exceed the 18 percent standard than before. Friedl et al. (15) have validated the reliability of the 4-compartment chart over the old 2-compartment method. The purpose of this study is to determine if the maximum value of 18 percent is a valid upper limit for body-fat based on a Marine's ability to perform within the appropriate levels of physical fitness established by the PFT.

5. Validity in Testing Strength and Muscular Endurance

The Marine Corps use of the term "dead-hang" pull-up inappropriately implies a measure of static strength is to be measured, but static strength is correctly measured with a maximum steady exertion sustained for approximately 4 seconds (e.g., the weight lifting events in the Olympics). During a recent physical fitness conference held by the Marine Corps, doctors argued that the successful execution of one dead-hang pull-up (as the implied static measure of strength) was sufficient demonstration of one's shoulder strength capability. The doctors' arguments thus question the validity for testing to an upper limit of 20 repetitions (a dynamic measure). The British Royal Marines only require 15 repetitions as an upper limit in demonstrating physical strength. Multiple repetitions of a pull-up more accurately resemble a dynamic muscular strength test, because of the dynamic nature of the activity and the variance in the strength capability as a function of the position of the arms in space and/or the speeds of movement involved (Ayoub, Gidcumb, Reeder, Beshir, Hafez, 1981). Few quantitative data are available at this time on the subject of measuring strength under dynamic conditions; it is likely to be very difficult and often impractical, if not impossible, to define and maintain control of the muscles to be measured, and those to be excluded (Kroemer 1986). Antinori et al. (1988) reported low efficiency in performing pull-ups due to the isometric forces exerted on the wrist in maintaining the balance in alignment with the center of gravity and the grip. The pull-up has not been validated as a measure of absolute muscular strength or endurance. Pate et al. (1993) reported the pull-up test to be a moderately valid measure of absolute muscular strength; however, there was no support for concurrent or construct validity of the pull-up test as a field measure of muscular endurance. As a result of the Marine Corps implementation of the new dead-hang pull-up standards, men's scores have plunged down in some cases by 40 or more out of a total 300 possible points (Fuentes, 1997).

The MCO on Physical Fitness Testing describes the pull-up event as a test of strength and stamina of the upper body (shoulder girdle). In an effort to ensure a valid test of upper body strength, the Marine Corps implemented a policy requiring pull-ups to be executed from a dead-hang position and to be performed without any swinging, kicking, or kipping movement. Kipping (previously allowed in execution of a pull-up) is a term Marines use to describe the act of swinging the body in a gymnastic pendulum motion in order to create a momentum effect in conducting multiple pull-up repetitions.

It is not evident that the pull-up test is a valid measure of absolute muscular strength or muscular endurance. There are good reasons to view the validity of such tests as problematic. For one, it seems likely that performance is confounded by body weight, which is the resistance overcome in performing these tests. Several studies have found that pull-up performance scores are 'markedly confounded by body weight' (Pate, Ross, Baumgartner, & Sparks, 1983; Cotton, 1990). In activities where body mass is repeatedly lifted against gravity, extra 'mass' in the form of fat or large muscle mass is disadvantageous (Grant, Hynes, Whittaker, & Aitchison, 1996). The theoretical effects involving biomechanical sciences and anthropometry support the concern that pull-ups are confounded by weight. The development of the biomechanical sciences is closely linked to Newton's physical laws (Kroemer 1986). Generally speaking, it is expected that a taller man should be able to produce more muscular strength than a shorter man. But the advantage of the taller/stronger man is offset by his longer lever arms, since the ability to lift one's own body (i.e., do a pull-up) is inversely proportional to the length of one's arms. The larger and stronger man is actually handicapped by his greater body weight when he has to lift his body, as when chinning the bar (Astrand, 1986).

The biomechanical loading exerted on the body during the execution of a pull-up is based on the position of the body mass (center of gravity) relative to the axis of rotation of the shoulder joints. This position relative to the axis of rotation is called a moment. A moment is defined as the product of force and distance. Thus, a large 800 Newton mass (179.85 lb. force) individual with a 75cm (29.53 inches) arm length imposes a moment of approximately 600Nm (800N*0.75m) on the shoulder joints (combined). A smaller 600 Newton mass (134.89 lb. force) individual with a 65cm (25.59 inches) arm length imposes a moment or load of only about 390Nm (600N*0.65m) on the shoulders. Thus, with regard to the amount of work required to execute a pull-up the individual with a 75cm arm length is at a disadvantage compared to the individual with a 65cm arm length. Figure 1 illustrates the effect of body size differences on internal moment loads.

Marines are allowed to grasp the pull-up bar using either a forward or reverse grasp technique, while often wondering which method is actually more efficient. Antinori et al. (1988) found during the execution of pull-ups that elbow and wrist moments were notably negligible with reverse grasp (not so with forward grasp), while the forward grasp on the horizontal bar was shown to produce greater moments acting on the shoulder joint than the reverse grasp. These results indicate that the reverse grasp method is the more efficient method with regard to moments acting on

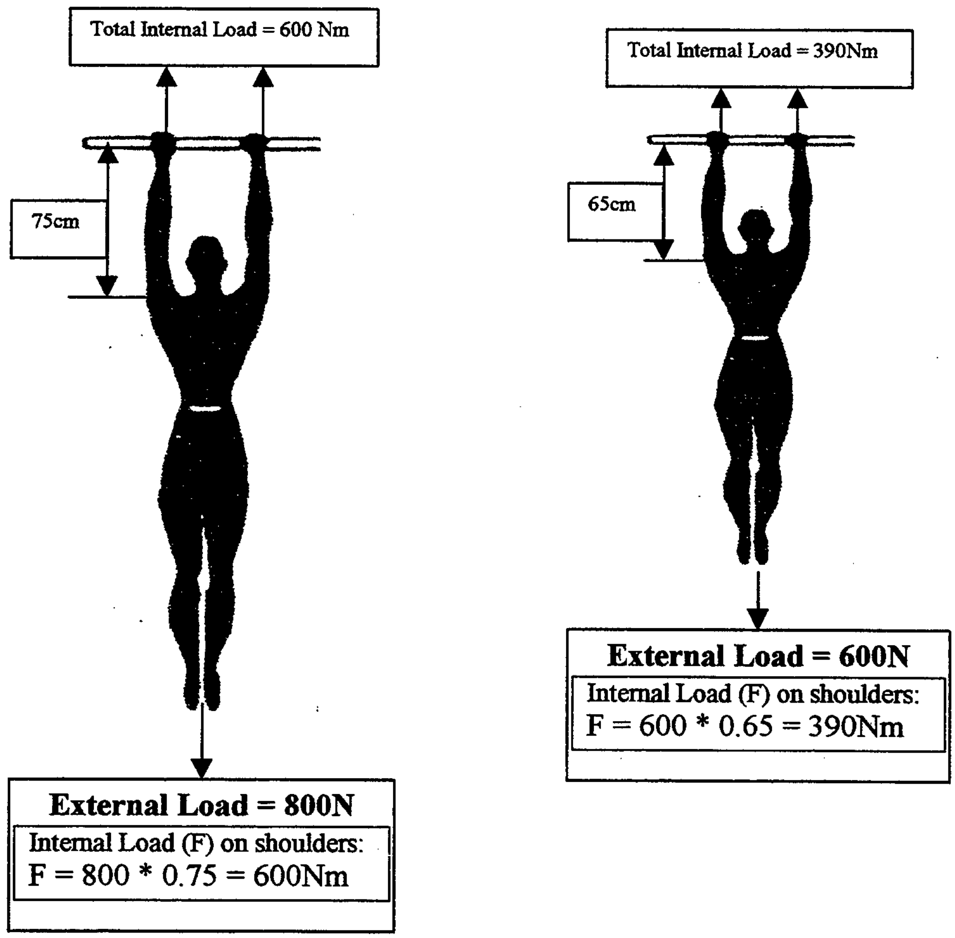


Figure 1. Internal moment or load for pull-up on shoulders of different sized individuals. External loads refer to those forces that are imposed on the body as a result of gravity. The external load is counteracted by an internal load that is supplied by the muscles of the body. This Figure shows that the internal load (shoulder muscle) acts at a distance relative to the arm length.

the primary joints. Their study also showed that inter-individual differences in the pull-up performance were notably great, resulting from differences among body masses and length of body segments.

6. Equitability of three PFT Events

Many Marines believe the recent change to require dead-hang pull-ups will lead to Marines being stronger and in even better shape. The new requirement will drive more Marines to go to the gym in an attempt to build true upper body strength. With the extra time required to improve shoulder strength, Marines could find themselves in the dilemma of balancing anticipated gains with expected losses. Most Marines carefully plan out their own training programs to establish the best strategy to attain a certain level of success on the PFT. Some have recognized the tremendous value of a single pull-up at 5 points per repetition. Table 1 gave the number of points earned based on physical performance for the three PFT events. For example: with time, effort and the proper strength program, an improvement of 2 pull-ups on the PFT is worth an additional 10 points. Ten more points for the extra work of 2 pull-ups might be considered ample compensation for the training time and effort required to improve 1 minute and 40 seconds on the 3-mile run, which is worth the equivalent 10 points.

This raises some concern for the Corps, especially if it can be shown that Marines are unintentionally sacrificing their run times to improve their strength. Thus, Marines should be cautioned about bulking-up too much and dedicating too much time to improving upper body strength. Bulking-up too much is likely to lead to weight gain and could prove to be counter productive since 'pull-ups are confounded by weight' (Pate, Ross, Baumgartner, & Sparks, 1983; Cotton, 1990). Dedicating too much time to upper body strength and not enough time to maintaining an efficient level of cardiovascular endurance could lead to decreasing overall fitness levels and even lower PFT scores. The implementation of the dead-hang pull-up has resulted in a greater spread for the pull-up scores, but a greater 'inequity' when compared to the scored distributions for either the run or the sit-up events. For example, typical scores for the 3-mile run range from 75 to 85 points, and typical sit-up scores range from 85 to 95 points (new sit-ups are assessed at approximately 80 to 90 points), while typical 'dead-hang' pull-up scores range from 50 to 70 points out of a possible 100.

D. PURPOSE

The purpose of this study is to examine the current active duty weight and body-fat standards based on the performance of Marines on the physical fitness test (PFT). The study will investigate alternative standards to determine whether relaxing the maximum weight and/or percent body-fat standards can be justified without resulting in significant decreases in physical fitness performance. In addition, the study will analyze whether dead-hang pull-ups are a fair predictor of physical strength and muscular endurance based on body size, and whether the scored performance distribution for pull-ups is 'equitable' in comparison with the scored performance distributions for the run and new sit-up events. This study will present the pros and cons of re-scaling the scoring system for the dead-hang pull-ups, as well as proposing a new three profile PFT alternative comprised of aerobic, muscular and body-fat profiles.

II. METHODS

A. DATA COLLECTION

1. General

Three separate sets of data were collected to allow a thorough analysis of the issues of weight, body-fat, and physical fitness. Although the data sets were carefully gathered from a broad range of male Marines, they were not randomly selected from the full population. Therefore, caution must be used when generalizing about all Marines. MCO 6100.3J Physical Fitness requires each Marine to participate in a minimum of 3 hours of physical fitness training per week, to be tested semiannually, and to obtain a minimum level of third class on the PFT (see Table 2 for classification levels). The attainment of a higher level score is encouraged as a reputable individual goal. Failure to meet the minimum requirements in any event constitutes failure of the entire test. Superior physical performance is achieved by scoring 285 or more out of a possible 300 points (100 points for each of 3 events). Recognition of superior physical fitness is encouraged and recommended for all commands. Promotion/advancements are important incentives for individuals performing with maximum effort to attain higher PFT scores. For the purpose of data analysis for this study, individuals who only took a partial PFT (did not participate in all three events) were removed from the data sets.

2. Data set 1: Subject Participation Study

This data set was collected by means of a participation survey study, which was conducted in November and December of 1997. This study included 223 subjects ranging in age from 18-43, and comprised over 78 different MOSs. The participants are from the Marine Corps University's staff NCO academy (advanced, career and sergeants courses), the Marine Corps Combat Development Command's operations company (audiovisual support, photo, and band), The Basic School's enlisted instructor company, and the Defense Language Institute's Marine Corps Detachment students. Since unit records do not include anthropometric measurements for determination of percent body-fat (percent B.F.), this study took appropriate circumference measurements for all participants in accordance with ALMAR 326/97, 'Change 3 to MCO 6100.10B, Weight Control and Military Appearance.' Data recorded for each individual include age, rank, MOS, height, weight, neck, waist, percent B.F., pull-ups, sit-ups, run-time, and PFT scores (including scores for both the old and new PFT requirements). Additionally, subjects participated in a pilot study questionnaire to assess opinions of the current weight, percent B.F., and PFT standards.

3. Data Set 2: Unit Records

This data set includes the historical PFT scores for 430 subjects, which were provided from 6 representative command organizations' training files. PFT records were collected from: the Marine Corps University's staff NCO academy (advanced, career and sergeants courses); the Marine Corps Combat Development Command's operations company; The Basic School's enlisted instructor company; and the Defense Language Institute's Marine Corps Detachment. The subjects ranged in age from 18-42, and include over 78 different MOSs. Recorded data was limited to age, rank, MOS, height, weight, pull-ups, sit-ups, run-time and PFT scores (including scores for both the old and new PFT requirements). All PFTs were executed in accordance with MCO 6100.3J, Physical Fitness and revision ALMARs 070/96 and 213/96. A subset of the data includes a control group of 42 subjects who participated in a Commanding General's Physical Fitness Test Inspection. An additional data set of 312 comparable PFT scores from these same commands were gathered in accordance with MCO 6100.3J prior to the implementation of the new 'dead-hang' pull-up requirement. Coincidentally, 62 individuals within these commands were recorded as participants in both the old and new PFTs.

4. Data Set 3: OCS Unit Records

This data set is comprised of 200 male officer candidate records ranging in age from 21-32. Although officer candidates are not a representative random sample of the general Marine Corps population, the availability of the large quantity of physical fitness events that are conducted, evaluated, and graded will allow qualitative generalizations to be made from the empirical results. These results will provide an indication of whether or not 'dead-hang' pull-ups are a fair predictor of physical strength and muscular endurance as required in the other strength and stamina graded events. However, the quantitative magnitude of these estimates strictly applies to the types of personnel represented. Sample data includes height-weight, neck, waist, percent B.F. measurements, PFT scores (pull-ups, sit-ups, 3-mile run), as well as scores made on the obstacle course, endurance course, combat conditioning course (push-ups, rope, carry, fire and movement), and conditioning hikes.

As a test of upper body strength and muscular endurance, officer candidates are required to negotiate a 100-yard obstacle course comprised of seven major obstacles separated by low hurdles. Officer candidates must complete the course in a time limit of 2 minutes to pass, and within 1 minute for a maximum score of 100 points. The obstacle course consists of the following obstacles: low vault, single horizontal bar, combination obstacle, the wall, high log vault, four-vault log sequence, double horizontal bar, and a 20-foot rope climb.

As a test of stamina and muscular endurance, officer candidates are required to complete an endurance course within a time limit of 43 minutes to pass, and within 33 minutes for a maximum score of 100 points. The endurance course consists of the sequential execution of: the 100 yard obstacle course, a 3-mile run (with combat gear), a stamina course, and a partial combat course. This challenging test of stamina and muscular endurance provides an ideal measure of the overall physical fitness of Marines.

5. Data Set 4: Modified Sit-up Experiment

This data set is comprised of 83 male service members from the Defense Language Institute. Subjects ranging in age from 18-40 participated in an experiment in accordance with ALMAR 369/97 "Change 2 to MCO 6100.3J Physical Fitness," which requires the execution of the new modified sit-up effective 1 July 1998. The experiment was designed to assess the expected range of scores for the modified sit-up to forecast the equitability in scoring the three PFT events, and investigate the need for re-scaling the scoring system for the 'dead-hang' pull-up. Vastly different means and distributions among the three PFT events indicate a need for adjusting the current scoring system in order to weight all three events more equally, as originally intended with the 300-point scale.

B. PROCEDURE

The analysis will be conducted in three phases: Phase I will consist of basic data analysis techniques utilizing data set 1 to investigate the relationships between physical fitness performance and the body composition variables of percent body-fat, weight, and body mass. Both body mass and percent B.F. can be converted into percentile terms in comparing alternative weight and percent B.F. standards based on PFT scores. The main effort is to show that the current Marine Corps standard of a maximum limit of 18 percent body-fat is too strict, and that it is unrealistic for a significant portion of otherwise physically fit Marines (1^{st} class PFT scores). An objective is to show that the body-fat standard can be slightly relaxed to a reasonable limit beyond the 18 percent B.F. at which it can be said that the physical performance of male Marines is likely to be hampered. A major intent is to analytically show that excess body weight (body mass) does not have as much negative influence on physical fitness performance as excess body-fat. In the process, it will be shown that body weight is not the best screening tool to identify Marines who are both over-fat and in poor physical fitness. It will also be shown that since body weight does not have a strong negative relationship with performance on the PFT qualification scores the addition of about 2 lbs. for each height can be justified without significantly influencing physical performance. This is simply accomplished by establishing the maximum weight limits at a standard 85th percentile body mass for each respective height.

Phase II will consist of basic data analysis techniques to investigate the validity and relationships of the 'dead-hang' pull-up test with the PFT using both data sets 1 and 3. First, using data set 1, the pull-up test will be confirmed to have a confounding relationship with weight and body-fat. Then the dead-hang pull-up scores will be analytically compared with the 3-mile run and the sit-up scores, using the run test scores as a base case to explore viable pull-up scoring alternatives. The general idea is that an average performance on the pull-up test should be expected to receive about the same score as the average performance on either of the other two events. Several other options could be modeled to determine which pull-up scoring system is best based on the assumption that all three PFT events should be weighted equally and without prejudice. The intent is to provide fair compensation to large, healthy, strong Marines by investigating a formula that computes the total amount of work produced in execution of the pull-up test, and to provide a fair score for that work. The total work formula for pull-ups will be studied using both data sets 1 and 3. Additionally, the pull-up test (old and new) will be analytically compared with several strength and endurance tests from data set 3 to show that pull-ups do not provide a true indication of upper body strength and muscular endurance.

Phase III will present analyses of the best alternative scoring methods for the 'dead-hang' pull-up in order to produce more equitable distributions among the three PFT events. Table 18 shows the current scoring system along with variations for proposed alternatives. If it is shown in phase II that pull-ups are confounded by weight, it is not unreasonable to assume that the Marine Corps will continue to administer this as a test of muscular endurance because of its simplicity in administering to Marines around the globe. Therefore, a scoring system will be proposed for the pull-up test, which provides a fair and just compensation for all Marines. Simple and multiple linear regression will be used to describe, study, and compare alternative methods for evaluating and measuring the level of physical fitness of Marines, and to examine adjustments in the overall PFT. An alternative PFT comprised of the following three profiles: aerobic (run), muscular (pull-up, push-up, sit-up), and body-fat will be investigated along with proposed scoring methods for the three profiles.

The fitted regression models derived from the observed data estimate an assumed relation between a dependent variable, Y, and one or more independent variables. The estimated models which result describe the 'best fitting' equation linking Y to the independent variables, based on the data observed. This equation describes an association between the variables observed and does not necessarily imply any degree of causality. Thus, caution must be used in interpreting causation from regression results.

III. RESULTS

A. ANALYSIS OF BODY COMPOSITION STANDARDS BASED ON PHYSICAL PERFORMANCE

Descriptive statistics for data set 1 were computed on all weight, percent body-fat estimates, and physical fitness scores. Descriptive statistics for Marines in this sample are presented in Table 6. The Marines in this study were approximately the same height and weight as those found in previous studies conducted by Dr. Rupinski for the Marine Corps. The mean heights and weights determined in this study are also comparable to the Bureau of the Census, which found an average height for 25 to 34 year-olds of 69.6 inches and average weight of 173 lbs.

Table 6. Sample Summary Independent Measures.

Measure N = 223	Age	Height	Weight	Body-Fat	Body Mass (kg/m^2)
Min	18	62.50	118.00	1	18.26
Mean	26.42	70.03	173.93	14.3	24.98
Median	25	70	176	14.0	25.25
Max	43	76.50	253	28	33.38
S.D.	5.79	2.59	23.03	5.14	2.79

1. Analysis of Weight Standards

In order to investigate the relationship between body weight and physical performance, each Marine's weight was converted into body mass and subsequently translated into percentile terms using the conversions from Table 7. Since weight limits vary for each height, and body mass is determined by both weight and height (weight/height^2), body mass is used as a simple measure in obtaining and justifying standardized weight limits for each height. Presented in Figure 2 are the generally consistent positive relationships between the body composition elements (mass, body-fat, and weight) and the respective percentile body mass groups. The top left display of Figure 2 shows the smooth positive relationship between body mass and the respective percentiles of body mass, which were determined from data set 1 and the conversions provided in Table 7. The top right and bottom left displays of Figure 2 show generally positive relationships exist for both body-fat and weight with the respective body mass percentiles grouped in five point intervals. The lack of consistently positive trends is attributed to the small sample sizes within each five-point interval from the respective percentiles of body mass. Also shown in Figure 2 is the relationship the median PFT scores have with the respective body mass percentile groups. There is generally a downward trend in the overall mean and median PFT scores for increasing body mass groups, but the plot is too unstable to indicate a precise body mass level at which performance is hampered. The largest change in mean and median scores in comparison with the fifth percentile group (control group) is observed after the 75th percentile group. However, any significant decreasing trends are negated with respectable scores obtained by the 86th to 90th percentile group. Thus, there are no consistently negative trends shown by decreasing PFT scores from group to group mainly because of small sample sizes. These observations are confirmed with the box plots of percentile body mass vs. PFT performance shown in Appendix A.

Table 7. Conversion of Body Mass to Percentiles.

Percentile	BodyMass	Percentile	BodyMass	Percentile	BodyMass	Percentile	BodyMass
5	19.35	30	22.07	55	24.11	80	26.95
10	20.20	35	22.42	60	24.56	85	27.79
15	20.69	40	22.86	65	25.10	90	29.16
20	21.23	45	23.26	70	25.61	95	31.06
25	21.64	50	23.66	75	26.23	100	53.03

(Rupinski, 1989).

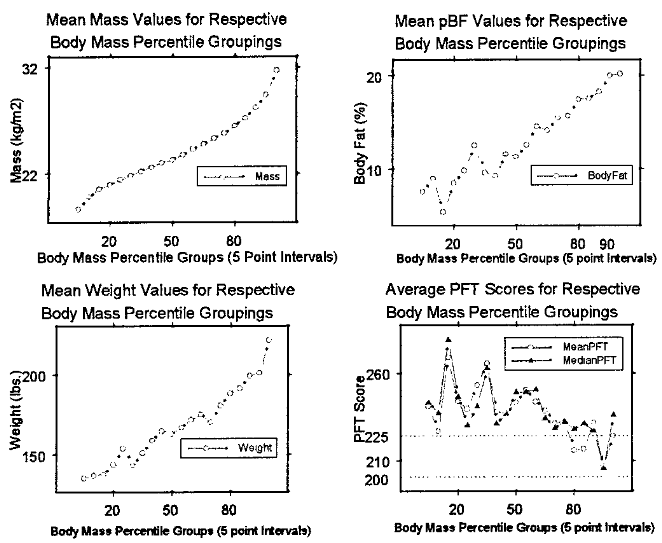


Figure 2. Mean trends in mass, percent B.F., weight, and PFT scores based on fifth percentile groupings for body mass (data set 1).

To investigate how PFT scores are influenced by weight, the correlation matrix shown in Table 8 indicates that weight is significantly related to all the listed fitness variables except for sit-ups. The strongest correlations are indicated with the expected positive relationship weight has with body mass (R=0.80), body-fat (R=0.59), and height (R=0.55). These results confirm the premise that heavier people tend to be larger in stature and overall body size. Weight is also positively correlated with age (R=0.16) indicating that as individuals get older they tend to gain weight. Pull-ups and PFT scores have a significant negative relationship with weight (R=-0.24). A positive correlation coefficient for run times (R=0.24) indicates that heavier individuals tend to have longer run times which lead to lower scores, thus resulting in a negative relationship between weight and run scores.

Table 8. Correlation Matrix for Fitness Variables, n = 223.

Variables	1	2	3	4	5	6	7	8	9
1. Age	1.00								
2. Height	-.08	1.00							
3. Weight	.16*	.55*	1.00						
4. Body-Fat	.36*	.05	.59*	1.00					
5. Mass	.26*	-.00	.80*	.64*	1.00				
6. Pull-ups	-.12	-.12	-.24*	-.51*	-.19*	1.00			
7. Sit-ups	-.21*	-.02	-.05	-.20*	-.03	.31*	1.00		
8. Run Time	.17*	-.02	.24*	-.34*	.28*	-.49*	-.34*	1.00	
9. Score	-.21*	-.07	-.24*	-.49*	-.22*	.88*	.63*	-.75*	1.00

* Significant at $\alpha = 0.05$, for Correlation Coefficient R >= 0.1307.

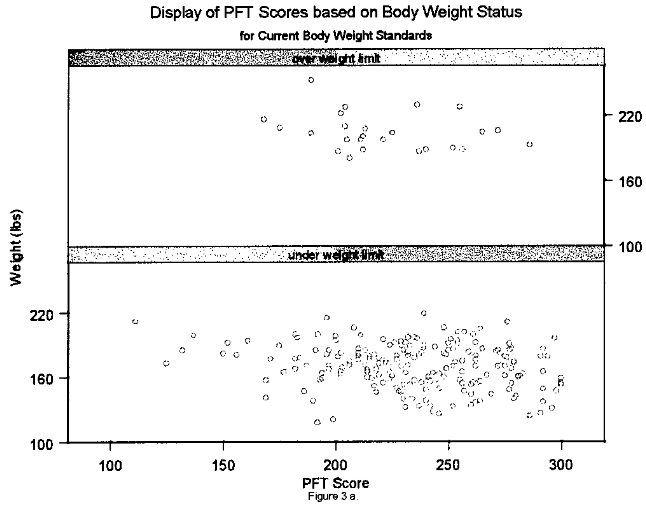
A reason for investigating the validity of the maximum weight limits is to determine if they can be adjusted to alternative weight limits, which are derived from the respective 85th percentile body mass for given heights. The Marine Corps' maximum weight standards, as shown in Table 3, range between the 82nd and 84th percentile body mass for given heights. Since body mass is a standard method for relating weight and height in a single measure, it seems logical that the maximum weight limits could be set at consistent percentile levels of body mass with respect to each height. Given the relationship: body mass (kg/m^2) = weight (kg)/ height (m^2), the conversion to percentiles of body mass (Table 7) makes it possible to solve for consistent weight limits for each height based on an acceptable percentile body mass value. The current weight limits are not set at a given percentile body mass level, or with any statistical basis of acceptable levels of physical performance.

The diagrams in Figure 3 provide a visual comparison of PFT scores based on the current weight standards and the proposed 85th percentile body mass limit. Individuals who exceed their given weight limits are depicted in the upper panel Figure 3 (a) and (b), which does not indicate that their scores are any worse than those who are within their respective weight limits. Individuals who exceed the weight limits proposed with the respective 85th percentile body mass are depicted in the upper panel in Figure 3 (b), which does not appear to be significantly different than that depicted in Figure 3 (a). The fact that individuals deemed as overweight are capable of performing just as well as those deemed within the weight standards is an indication that the maximum weight limits are set too low. The results of these findings indicate that the current weight limits can be relaxed to a consistent limit without resulting in significant decreases in overall physical performance.

The results of a two sample t-test comparison between the PFT scores for Marines between the 80th and 85th percentile body mass and those between the 70th and 80th percentile body mass are shown in Table 9. With a p-value of 0.6363, there is apparently no significant difference in PFT scores between the two groups.

Table 9. Results of Two Sample t-Test Comparison of PFT Scores for Marines between the 70th to 80th Percentile Body Mass Group vs. those between the 81st to 85th Percentile Body Mass group.

Percentile Body Mass	Between 70th-80th	Between 81st-85th
Total N	47	24
Mean PFT Score	225.42	221.04
Std Dev	33.842	43.703
Std Dev (pooled)		37.419
t-value		0.467
p-value		0.642



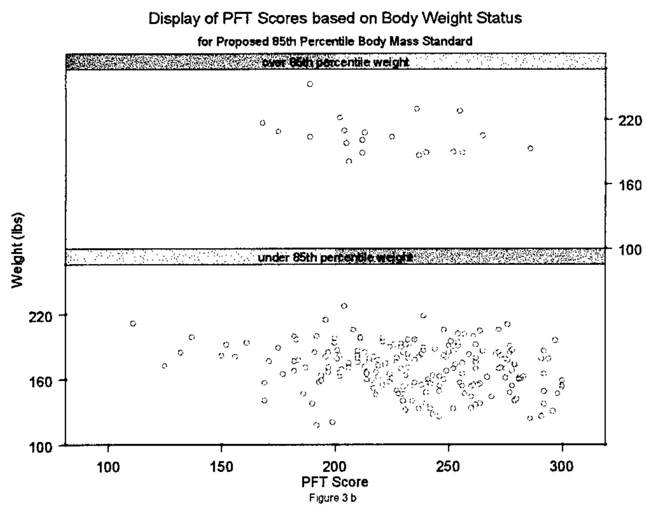


Figure 3. Comparison of the Relationships between the Current Weight and the 85th Percentile Weight Limits with Respect to PFT Scores. The Upper Panels of 3 (a), and 3 (b) show that Marines deemed Overweight have Similar PFT Scores, with many Scoring Over 200 points (data set 1).

To further analyze the relationship of acceptable weight limits with PFT scores goodness-of-fit tests were conducted using contingency tables based on the number of qualification scores for first, second and third class levels of fitness. The null hypothesis is that PFT class (1st, 2nd, or 3rd) is independent of different maximum allowable percentiles of body mass. Table 10 results in a goodness-of-fit statistic $C_2 = 1.597$, so we fail to reject the null hypothesis (at $\alpha = 0.05$). Therefore these data are consistent with samples from populations which are the same; i.e., the distributions of 1st, 2nd, and 3rd class scores do not change with body mass groups. In particular, increasing the standards to allow individuals to have body mass at the 85th percentile would not be expected to change the PFT score distribution.

Table 10. Contingency Table for Determination of Independence Between Fitness Class (based on PFT Scores) and Body Mass Percentiles.

Percentile Body Mass	Number of Scores Qualifying in Fitness Classes		
	1st Class	2nd and 3rd Class	Total
Under 80th	123	50	173
81st to 85th	16	9	25
Over 85th	15	10	25
Total	154	69	223

For $\alpha = 0.05$, df = (3-1)(2-1) = 2, $\chi^2_{.95,2} = 5.991$, G.O.F. statistic $C_2 = 1.597$.

Several linear regression models were run using the S-PLUS 4.0 software program as an additional means of analyzing relationships and predictability among the fitness variables. The results of a step-wise linear regression model with PFT scores being modeled by height, weight, body mass, and percent body-fat resulted in percent B.F. and body mass as the most important variables with significant p-values of 0.000 and 0.036 respectively. To determine the predictability of body-fat by weight, percent B.F. was modeled by weight resulting in a significant p-value with an R-squared of 0.352. Similarly body-fat was modeled by mass, which also produced a significant p-value and an R-squared of 0.404. The significant p-values for both regressions indicate further support that body-fat is related to both weight and mass, but neither R-squared value is impressively large enough to serve as an adequate measure for predicting body-fat. Figure 4 illustrates the fact that 23 percent of Marines (from data set 1) exceed the maximum body-fat standard of 18 percent B.F. (data in upper panel). Even more alarming is that 68.63 percent of those individuals are under their maximum weight limits for their respective heights. The most significant revelation shown by Figure 4 is that the lowest PFT scores (less than 160 points) tend to come from individuals who meet their maximum weight limits, yet exceed the current body-fat standard. Thus, the use of semi-annual weigh-ins as a tool to screen for individuals who are likely to have excessive body-fat percentages (and thus poor PFT scores) is not very reliable.

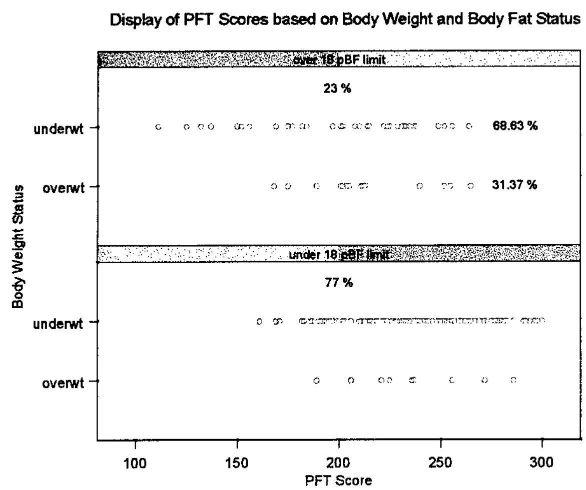


Figure 4. Relationship of Body Weight and Body-Fat Status's with PFT Score. The upper panel indicates that 68.63% of Marines deemed fat are actually under their maximum weight limits. The lowest PFT scores are associated with this group of Marines (data set 1).

2. Analysis of Percent Body-Fat Standards

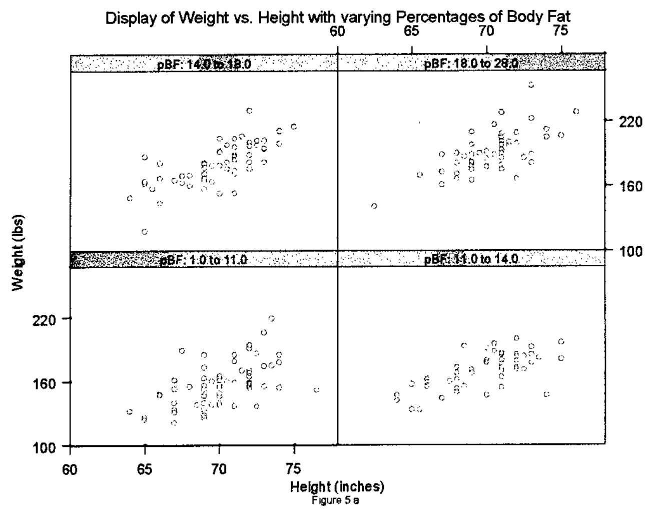
As an assessment of the proportion of the sample being overweight and/or over-fat, Table 11 and Figure 5 (b) indicate that an individual who is over-fat is not necessarily overweight and vice versa. Comparing the four plots in Figure 5 (a) confirms the obvious assumption that heavier individuals tend to carry more body-fat. Although a surprising 23 percent of the Marines sampled were deemed over-fat and 11.2 percent were actually overweight, only 7.2 percent were overweight and over-fat. This means an alarming majority (68.63%) of Marines who exceed the 18 percent body-fat standard actually meet their respective weight requirements for their height. The graph in Figure 5 (b) provides the reader with a visual representation of how individuals who are over-fat are not necessarily overweight, and vice versa.

Table 11. Proportion of Sample Overweight and/or Over-Fat from Anthropometric Survey Data:

Overweight Requirement: (Sample Population = 223) **25/223 = 11.20%** **Overweight and Body-Fat 16/223 = 7.17%**	
Overweight And Under 18% Body-Fat 9/30 = 36.00%	Overweight And Over 18% Body-Fat 16/30 = 53.33%
Over 18% Body-Fat Requirements: **(9 Are Exactly At 18 pBF = 4.04%)** **51/223 = 23%**	
Over 18% Body-Fat and Overweight 16/51 = 31.37%	Over 18% Body-Fat and Underweight 35/51 = 68.63%

Alternative 20% Body-Fat	
Between 19 to 20% Body-Fat 26/223 = 11.66%	Over 20% Body-Fat 25/223 = 11.2%
Alternative 85th Percentile Weight Limit	
Over 85th Percentile Weight 20/223 = 8.97%	Over 85th Percentile Weight and 18% Body-Fat 13/223 = 5.83%

The reader can visualize this situation by noting the group of individuals who are categorized as overweight, but whose body-fat estimates fall below the 18 percent B.F. limit.



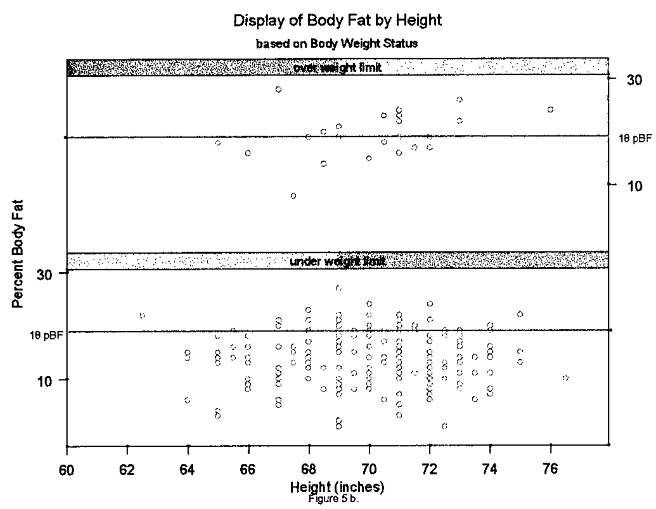


Figure 5. Display of the relationship of key anthropometric measures with a representation of weight status and body-fat for Marines at given heights. The top-right and lower-left panels of 5 (a) indicate the different trends in body size with respect to percent B.F. The lower panel of 5 (b) indicates that a large number of individuals deemed under weight are actually over the 18 percent B.F. standard. The upper panel indicates a large portion of individuals deemed overweight are within the 18 percent B.F. standard (data set 1).

The reader should also note that a large group of individuals who are deemed under-weight surprisingly have body-fat estimates above the 18 percent B.F. limit. The three diagrams shown in Figure 6 provide a visual summary of the fitness classification scores for the sample from data set 1. The classification of PFT scores by age groups

(Table 2) is amplified in Figure 6 (a) with individuals in the older age groups shown to qualify first or second class with lower scores than those required for the younger age groups. Figure 6 (a) indicates that the majority of the sample, 69.5 percent, qualified first class, 27.4 percent qualified second class, while only 3.1% qualified third class. There were no recorded failures. The plots presented in Figure 6 (b) indicate that a large number of individuals who are deemed over-fat (exceed 18 percent B.F.) are able to produce PFT scores that qualify as second and even first class. Figure 6 (b) does provide justification for the need of a body-fat limit by showing that the majority of the third class scores are from individuals who exceed 18 percent B.F. On the other hand, the plots presented in Figure 6 (c) indicate that individuals who are deemed overweight produce PFT scores that are just as good as those who are underweight. In fact, the vast majority of the third class PFT scores are from individuals who are over-fat and under their respective maximum weight limits.

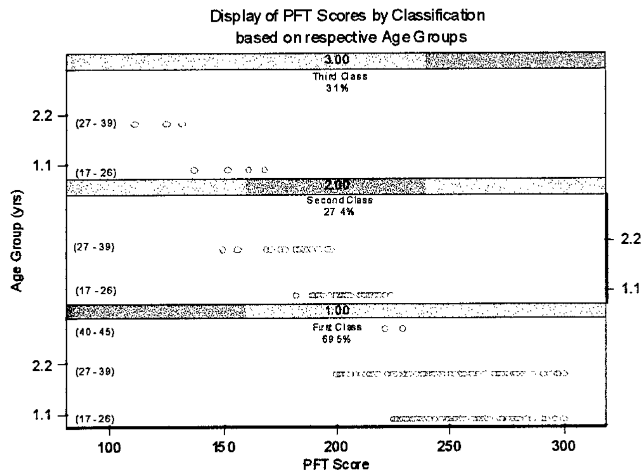


Figure 6 (a)

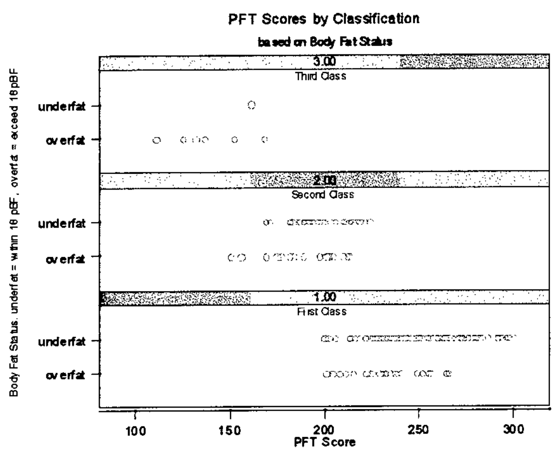


Figure 6 (b)

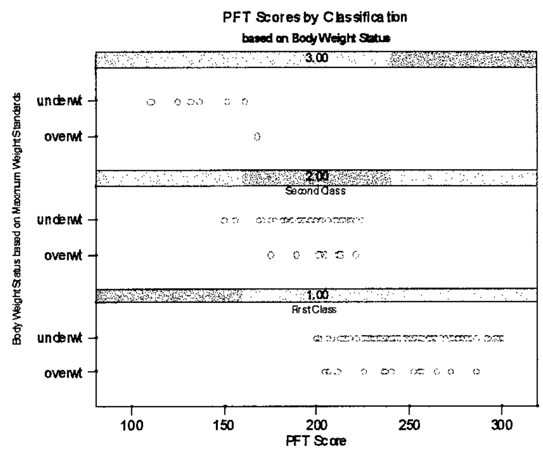


Figure 6 (c)

Figure 6 (a – c) Relationships of PFT classification scores with body composition status. 6 (a) shows PFT qualification scores based on respective age groups. 6 (b) shows that a large portion of Marines deemed over-fat perform just as well on the PFT as those deemed within 18 percent B.F. 6 (c) shows that Marines deemed overweight perform at least as well as those deemed underweight (data set 1).

The mean PFT scores for Marines, in all three events, tend to decrease as percent body-fat increases, as presented in Figure 7. The mean PFT scores shown in these plots are based on cumulative percentages of body-fat (i.e., the 59th percentile of this sample represents all Marines with less than or equal to 15 percent body-fat). Figure 7 shows that pull-up performance is affected the most with the increasing percentiles of body-fat, followed by the 3-mile run, while the sit-ups appear minimally effected. Because of the effects on the three PFT events, the combined PFT score is also negatively affected with increasing levels of body-fat. It is worth noting that the PFT line is the sum of the three event lines on the left; its negative slope is mostly due to the pull-up score. This relationship indicates that the pull-up has the most influence on the overall PFT score of the three events since the run and sit-up scores change less with increasing percent B.F. To make a determination of a valid limit at which a specific percent body-fat can be said to cause significant decreases in PFT performance requires examining the performance of individuals having specific percentages of body-fat. It is shown in Figure 8 that the median PFT scores do not significantly decrease in value until around 21 percent B.F., where scores drop from 217 for individuals at 20 percent B.F. to 191.6 for those at 21 percent B.F. This plot shows that the median PFT scores for all individuals exceeding 20 percent B.F. are well below the standard first class qualification score of 225 for the 17 to 26 age group. The box plots of percent body-fat vs. PFT performances, shown in Appendix A, provide additional representation of this trend. There is a large drop in average performance at the 6 percent B.F. mark, most likely caused by the small sample size at this level. However, the most relevant decrease in PFT scores is observed between the 20 to 21 percent B.F., for a decrease of 26 points for both the mean and median values.

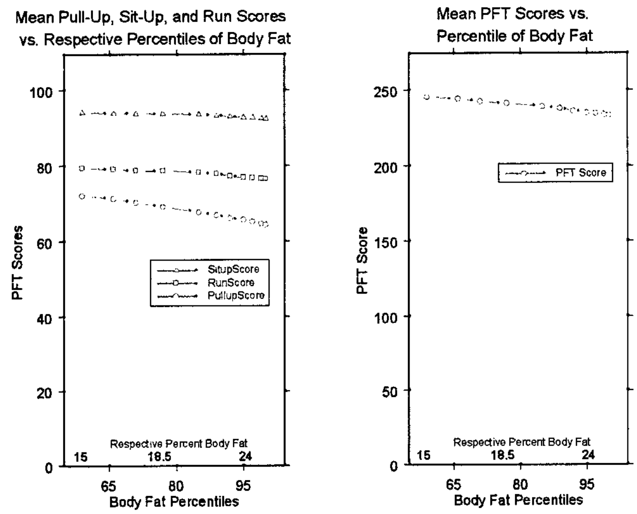


Figure 7. Mean PFT Scores for Proportion of Sample within Specific Percentiles of Body-Fat. The left figure indicates that not only are pull-up scores lower than the other PFT events, but it also has the steepest decreasing trend with increases in body-fat percentiles. The right figure represents the PFT score trends, which most resembles the effects of the pull-up scores (data set 1).

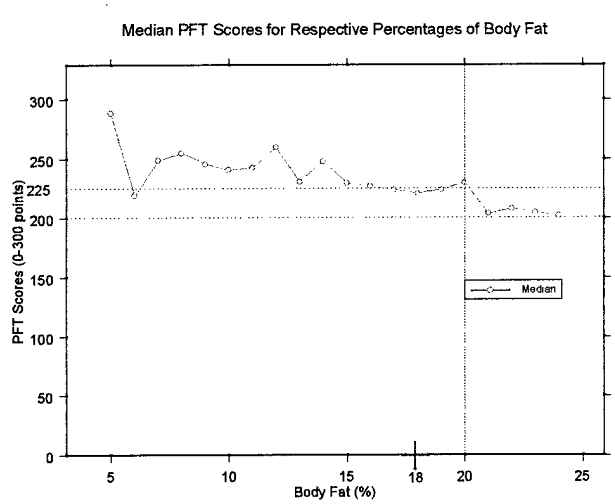
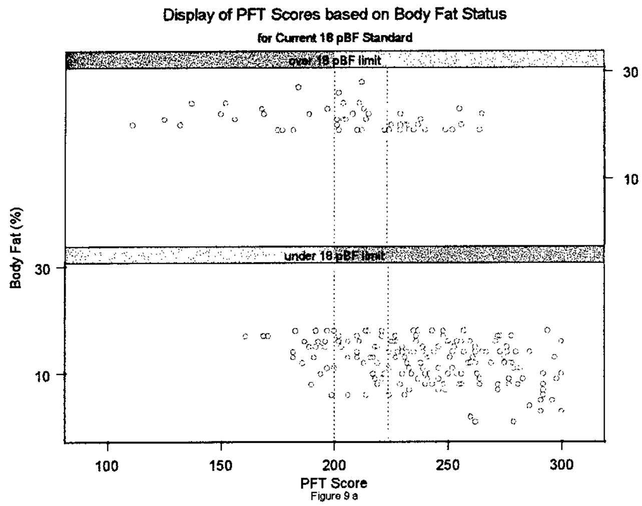


Figure 8. Median PFT Scores for Proportion of Sample with a Specific Percentage of Body-Fat (Maximum Score = 300 Points). Graph reveals that PFT scores decrease with increases in percent B.F. Scores do not significantly drop below the standard 225 point first class score until 21 percent B.F. (data set 1).

It is assumed that individuals having the maximum level of body-fat allowed by the Marine Corps (18 percent B.F.) are likely to perform within the acceptable Marine Corps physical fitness standards and fitness classes. Therefore, to investigate alternative maximum body-fat percentages, those individuals who were assessed with exactly 18 percent B.F. were used as a control group for comparing physical performance scores with individuals having higher levels of body-fat. The diagrams in Figure 9 provide a visual comparison of PFT scores based on the current 18 percent B.F. standard and the proposed 20 percent B.F. Individuals who exceed 18 percent B.F. are depicted in the upper panel of Figure 9 (a), which indicates a large number having satisfactory scores greater than 200 and even 225 points. This plot indicates individuals with estimates just above 18 percent B.F. typically perform as well as individuals within satisfactory levels of body-fat. Individuals who exceed 20 percent B.F. are depicted in the upper panel of Figure 9 (b), which shows fewer individuals having first class scores greater than 225 points. When compared with Figure 9 (a), Figure 9 (b) appears to provide a fairer depiction of capturing the expected relationship between excess body-fat and lower levels of physical fitness performance. The PFT scores for those having 18 percent B.F. were compared with those having 19, 20, 21, 22, 23, and greater than 24 percent B.F. using the standard two sample t-test. Table 12 shows the results of the respective two sample t-test comparisons. The PFT scores for Marines at 21 percent B.F. and those having greater than 24 percent were determined to be significantly less than those having the acceptable 18 percent B.F. (at $\alpha = 0.05$). The comparison of PFT scores for the group measured at 18 percent B.F. with the groups having 22 and 23 percent B.F. do not produce statistically significant p-values (at $\alpha = 0.05$). However, their respective mean scores of 203.57 and 208.25 are well below the minimum 225 points required to qualify first class on the PFT, and the sample sizes available at these levels do not provide a very powerful test for detecting differences in mean scores.



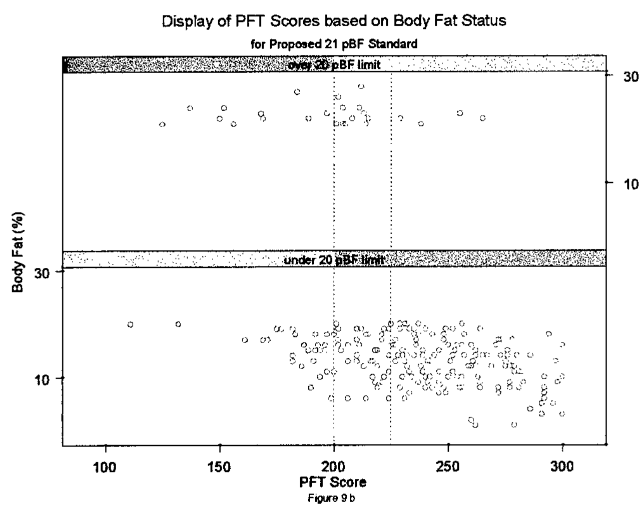


Figure 9. Comparison of the Relationships between the 18 and 20 percent B.F. Limits with Respect to PFT Scores. Comparing the top panels for 9 (a), and 9 (b) indicates that there are less first class PFT qualifying scores for the group of Marines deemed over 20 percent B.F., than there are in the group deemed over 18 percent B.F. (data set 1).

To further analyze the relationship of acceptable percentages of body-fat with PFT scores, goodness-of-fit tests were conducted using contingency tables which were tabulated based on the number of scores qualifying with first, second, or third class levels of fitness. The breakdowns for respective fitness classifications were shown in Table 2.

Table 12. Results of Two Sample t-Test Comparison of PFT Scores for Marines with 18 percent B.F. vs those with higher percent B.F. Levels.

Percent Body-Fat	**18%**	**19%**	**20%**	**21%**	**22%**	**23%**	**>24%**
Total N	**13**	**17**	**9**	7	7	4	7
Mean PFT Score	225.85	219.59	217.88	191.86	203.57	208.25	186.00
t-value		0.5693	0.5286	2.1669	1.4177	0.9628	2.7810
p-value		0.574	0.603	0.044*	0.173	0.351	0.012*

*Significant at $\alpha = 0.05$.

The null hypothesis is that PFT qualification score distributions are the same for various percentages of body-fat. The contingency table shown in Table 13 (a) results in a goodness-of-fit statistic C_2 of 16.316, thus the null hypothesis is rejected (at $\alpha = 0.05$) with a critical $\chi^2_{.95,2}$ of 5.991. This means that PFT qualification score distributions differ for the three body-fat groups. The contingency table shown in Table 13 (b) specifically addresses the independence of fitness classes for Marines within 18 percent B.F. and those having 19 and 20 percent B.F. This contingency table results in a goodness-of-fit statistic C_2 of 2.088, thus the null hypothesis fails to be rejected with a $\chi^2_{.95,1}$ of 3.841. That is, the fitness classification distributions of individuals with less than or equal to 18 percent B.F. and those with 19 and 20 percent B.F. may very well be the same, based on this sample. The contingency table shown in Table 13 (c) compares fitness classes for Marines within the proposed 20 percent BF standard and those with greater than or equal to 21 percent B.F. The goodness-of-fit statistic C_2 of 14.402 results in the null hypothesis being rejected, which indicates that the number of individuals qualifying in the respective fitness classes, for these groups, are dependent on body-fat. Marines with more than 21 percent B.F. are more likely to have a greater proportion of 2nd and 3rd class fitness scores than individuals within 18 and 20 percent B.F. limits.

Table 13 (a) Contingency Table for Determination of Independence Between Fitness Class (based on PFT Scores) and Percent Body-Fat.

Percent Body-Fat	Number of Scores Qualifying in Fitness Classes		
	1st Class	2nd and 3rd Class	Total
1 to 18 %	129	43	172
19 to 20 %	16	10	26
21 to 28 %	9	16	25
Total	154	69	223

For $\alpha = 0.05$, df = (3-1)(2-1) = 2, $\chi^2_{.95,2} = 5.991$, G.O.F. statistic $C_2 = 16.316$*.

Table 13 (b) Contingency Table for Fitness Class Independence (based on PFT Scores) for Marines within 18 percent B.F. and Marines within 19 to 20 percent B.F.

Percent Body-Fat	Number of Scores Qualifying in Fitness Classes		
	1st Class	2nd and 3rd Class	Total
1 to 18 %	129	43	172
19 to 20 %	16	10	26
Total	145	53	198

For $\alpha = 0.05$, df = (2-1)(2-1) = 1, $\chi^2_{.95,1} = 3.841$, G.O.F. statistic $C_2 = 2.088$.

Table 13 (c) Contingency Table for Fitness Class Independence (based on PFT Scores) for Marines within 20 percent B.F. and Marines Exceeding or Equal to 21 percent B.F.

Percent Body-Fat	Number of Scores Qualifying in Fitness Classes		
	1st Class	2nd and 3rd Class	Total
1 to 20 %	145	53	198
21 to 28 %	9	16	25
Total	154	69	223

For $\alpha = 0.05$, df = (2-1)(2-1) = 1, $\chi^2_{.95,1} = 3.841$, G.O.F. statistic $C_2 = 14.402$*.

3. Regression Analysis of Weight and Body-Fat Standards

Linear regression models were developed to examine the relationship between PFT performance scores and body weight (mass), body-fat levels, and other variables. Recall that the Marine Corps' categorization of the respective PFT classes (1st, 2nd, or 3rd) have different limits, depending on whether or not the person's age is below 27. Since the boundaries between the various PFT classes are lower for older Marines, the Corps recognizes that PFT scores are normally lower for older persons. Accordingly, data set 1 was partitioned into two parts, consisting of those Marines of age 26 or less (123 persons) and those of age 27 or more (the remaining 100 persons). Let

Y_i = PFT (total) score for person i
X_{1i} = age of person i
X_{2i} = height of person i
X_{3i} = body mass of person i
X_{4i} = percent B.F for person i
ε_i = the random error term for person i

The initial regression models fit for each of the two groups assumed the model

$$Y_i = b_o + b_1X_{1i} + b_2X_{2i} + b_3X_{3i} + b_4X_{4i} + \varepsilon_i;$$

regular least squares was used to estimate the unknown coefficients and the residual variation.

For the older Marines, the coefficient for body fat is highly significant (testing $b_4 = 0$ gives a p-value smaller than 0.00005), while the coefficients for height, age and mass are distinctly insignificant (p-values vary from 0.44 to 0.59). If the variables height, age and mass are dropped from the model individually, or in groups, the coefficient for body fat is the only one to differ significantly from 0 ($p < 0.00005$) and the others remaining are still distinctly insignificant. For the older Marines the inference seems clear: of the variables height, age, mass, and percent B.F., only percent B.F. has a significant effect on the average PFT score. With the variables as defined before, the simple model

$$Y_i = b_o + b_4X_{4i} + \varepsilon_i$$

fits the older Marines data quite well.

For the younger Marines, the coefficient for body fat is highly significant (testing $b_4 = 0$ gives a p-value smaller than 0.00005) and the coefficient for age is significant ($p < 0.05$), while the coefficients for height, and mass are distinctly insignificant (p-values > 0.05). If the variables height and mass are dropped from the model individually, or together, the coefficients for body fat and age remain significant ($p < 0.05$) and the other variable remaining is still distinctly insignificant. For the younger Marines the inference is also clear: with a model including the variables height, age mass, and percent B.F., only percent B.F. and age have a significant effect on the average PFT score. With the variables as defined before, the linear model

$$Y_i = b_o + b_1 X_{1i} + b_4 X_{4i} + \varepsilon_i$$

fits the younger Marines data quite well. The resulting model used to estimate PFT performance based on alternative levels of body-fat for the younger group included PFT scores being regressed on age and percent B.F., while the resulting models for the older Marines simply regressed PFT scores on percent B.F.

Some resulting PFT score estimates which were predicted from linear regression models using alternative body mass, or percent B.F. levels are shown in Tables 14 and 15. The next section will show that the current scoring method for the dead-hang pull-ups have problematic effects on the PFT score. Therefore regressions using a modified PFT score (combining the kip pull-up with the current sit-up and run scores) and a proposed PFT score (combines the prevailing dead-hang pull-up scoring alternative of 'Total Work Done' with the current sit-up and run scores) are shown in Tables 14 and 15.

Table 14 (a) shows the resulting PFT scores, which are predicted from the two linear regression models. Model A combines the pull-up scores from the Marines performance with kip pull-ups, with his current sit-up and run scores. Tables 14 (a) and (b) show that for both A type Models when the modified PFT score is regressed on percent B.F. (for younger and older Marines), first class PFT scores are comfortably retained with body-fat levels of 19 and 20 percent. The PFT scores for Model B combines the Marines current sit-up and run scores with the prevailing pull-up scoring alternative (from the next section) of 'Total Work Done.' The results from the B Models shown in Table 14 (a) and (b) indicate that at an alternative body-fat limit of 20 percent Marines are likely to score well above the minimum number of points, required for their respective age groups, to earn a first class PFT. In fact, the model using PFT scores with 'Total Work Done' for pull-ups indicates that older Marines having 20 percent B.F. would likely qualify first class with a score above the 225 points required for the younger age group. Confidence limits were predicted for the mean performance for both the young and old models labeled A and B, and the results indicated that first class PFT scores are maintained at the lower 95 percent confidence limit. Thus, these results suggest that the relaxation of the body-fat standard to 20 percent would not result in increasing numbers of PFT scores falling below the first class qualification scores for the two age groups.

It is interesting to point out that in the younger models the coefficient for age is 6 times greater in model A than model B, and similarly the coefficient for body-fat is almost 3 times greater.

Table 14 (a) Predicting PFT Scores from Linear Regression Models for Marines Under 27 Years of Age based on Alternative Levels of Percent Body-Fat. Model A represents the PFT scores predicted with the modified PFT (using kip pull-up with the current sit-up and run test) regressed on Percent Body-Fat and Age. Model B represents the projected PFT scores from the proposed PFT scores (with 'Total Work Done' used to compute the dead-hang pull-up score with the current sit-up and run test) being regressed on Percent Body-Fat and Age (data set 1).

Alternative Percent Body-Fat Levels (data set 1)	Predicted Old PFT Scores (with kip pull-ups) Regressed on Percent B.F. and Age.			Predicted New PFT Scores (with 'Work' computed for dead-hang pull-ups) Regressed on Percent B.F. and Age.		
	A N = 97, R^2 = 0.18 Coefficients: b_1 = -1.6, b_4 = -1.9			B N = 123, R^2 = 0.14 Coefficients: b_1 = -.26, b_4 = -.68		
	25%, 50%, 75% Quantiles for Age			25%, 50%, 75% Quantiles for Age		
	20 yrs	22 yrs	24 yrs	20 yrs	22 yrs	24 yrs
18	256.0	252.8	249.6	242.0	237.8	233.5
19	254.1	251.0	247.8	240.6	236.3	232.1
20	252.3	249.1	245.9	239.1	234.9	230.6

Table 14 (b) Predicting PFT Scores from a Linear Regression Model for Marines, Over 26 Years of Age based on Alternative Levels of Percent Body-Fat. Models A and B represent the respective PFT Scores from the modified PFT (kip pull-ups), or the proposed PFT (with 'Total Work Done' used to compute the dead-hang pull-up score) regressed on Percent Body-Fat.

Alternative Percent Body-Fat Levels (data set 1)	Predicted Modified PFT Scores (with kip pull-ups, and current sit-ups and run) Regressed on Percent B.F.	Predicted Proposed PFT Scores (with 'Work' computed for dead-hang pull-ups) Regressed on Percent B.F.
	A N = 100, R^2 = 0.163 Coefficient: b_4 = -2.57	A N = 100, R^2 = 0.164 Coefficient: b_4 = -2.82
18	257.8	233.8
19	255.4	231.0
20	253.1	228.2

As previously discussed, regressing PFT score on age, height, mass and percent B.F. clearly shows that any effect of mass on PFT score is accounted for by percent B.F., for both age groups. To examine how mass may affect the PFT score regression models were again employed (for each age group) using only age, height and mass. The results for both were the same, with height being insignificant. Thus, the two data sets were combined to fit a single model regressing PFT score on age and mass. The two groups were thus rejoined to encompass the entire 223-member sample. The resulting coefficients for age and mass remained significant (p = 0.022, and p = 0.008

respectively). The resulting model is used to estimate PFT performance based on alternative levels of body mass.

$$Y_i = b_o + b_1X_{1i} + b_3X_{3i} + \varepsilon_i$$

However, the resulting value for R^2 of 0.07 indicates that the mass and age model may have low predictive capabilities for PFT scores.

The results observed in Table 15 reveal that Marines between the ages of 22 to 31, who have a body mass level of 28 kg/m^2 (slightly above the 85th percentile) are all likely to qualify with PFT scores exceeding the respective minimum required to qualify first class for their age groups. In fact, a 22 year old Marine with a body mass level at the 92nd percentile is estimated to qualify with a first class PFT score of 225.7. Similarly, a 25 year old with a body mass level at the 90th percentile, or a 31 year old exceeding the 92nd percentile would both likely qualify with first class PFT scores of 225.1 and 216.9 respectively. This provides further evidence that the establishment of consistent weight limits at the 85th percentile of body mass for each height should not result in increasing numbers of PFT scores falling below the requisite points for the first class qualification for the two age groups.

Table 15. Predicting PFT Scores from a Linear Regression Model for Marines based on Alternative Levels of Percent Body-Fat and the respective 25%, 50%, and 75% Quantiles for Age. The Model Represents the PFT Score Regressed on Body Mass and Age (data set 1).

Alternative Body Mass Levels	Respective Body Mass Percentile	Predicted PFT Scores Regressed on Body Mass and Age (25%, 50%, 75% Quantiles) R-squared = 0.07 Coefficients: b_1 = -.98, b_3 = -2.3		
		22 years old	25 years old	31 years old
25	64th	237.4	234.5	228.6
26	73rd	235.1	232.1	226.3
27	80th	232.7	229.8	223.9
28	85th	230.4	227.5	221.6
29	90th	228.1	225.1	219.3
30	92nd	225.7	222.8	216.9

The interested reader will find some basic diagnostic plots for these regressions in Appendix H; since the data used were not a random sample from the Marine population, these may be of marginal utility. Figure H-1 shows four plots for the regression of the modified PFT scores on percent body-fat: fitted values versus residuals, fitted values versus observed values, normal quantile plot of residuals and a Cook's distance plot. The two plots of the fitted values illustrate the spread of the observed PFT scores over the range of the fitted values. This spread is greatest for fitted values near the middle of their range (the same fitted value results from a variety of observed scores) and is smaller at the extremes (the fitted value tends to be highly leveraged by extremes). Note as well that there are several extreme negative residuals. The normal quantile plot also shows rather extreme skewing of the residuals (to the left); any formal normal-based probability statements may not be very accurate as a result. The plot of Cook's distance shows the influence of the individual observations on the estimated coefficients. The same data points, which lead to the extremely negative residuals, are clearly evident on this plot as well. One might at this point delete these apparent outliers and refit the model. Since the desired result was an indication of the 'typical' relationship (including possible flaws) using all available data, this was not done.

In similar manner, figures H-2 and H-3 present the same diagnostic plots for the proposed PFT scores regressed on percent body-fat and for the PFT scores regressed on body mass and age for the complete data set. Much the same behavior is evident in these plots.

B. ANALYSIS OF DEAD-HANG PULL-UPS

1. Why Dead-Hang Pull-Ups Are A Controversial Test of Muscular Strength and Endurance for Adult Males

The pull-up has long been included in the Marine Corps' PFT battery. However, if physical fitness is defined as work capacity, it is important to determine the extent to which strength and weight of an individual influence the total number of pull-ups and total work done. The distribution of the number of pull-ups performed by the Marines in the sample is given in Table 16. The pull-up test has the broadest range of performance in comparison with the other PFT tests. Table 17 is a collection of the mean number of pull-ups for adult males, reported from a variety of other research studies. In each of these studies the standard pull-up (dead-hang) was conducted with participants attempting to execute the maximum number of repetitions until they could no longer execute a complete pull-up (by successfully raising their chin over the horizontal bar). Granted, experimental environments may have varied among experiments-- participant incentive and motivation may have been different, bar widths may not have been the exact same size-- but the general execution of a pull-up repetition with the instruction for participants to complete as many repetitions as possible remained consistent. This research indicates that a low number of pull-ups is common for adult males. This is enlightening information for Marine officials, responsible for assessing and justifying a scoring system for pull-ups, who may not be aware of the average pull-up trends for the general adult male population. It is apparent that trained, military, or otherwise elite athletes perform on average around 12 standard pull-ups, while the average untrained

Table 16. Distribution of Dead-Hang Pull-Ups. A wide ranging distribution indicates that half the Marines in this sample perform between 3 to 12 pull-ups, with respective scores ranging from 15 to 60 points out of a possible 100 points (data set 1).

# of Pull-Ups Max = 20; Min = 3	# of Marines N = 223	Percent Of 223	Percentile (inclusive)
<=7	20	9.0 %	9th
8	19	8.5 %	18th
9	16	7.2 %	25th
10	18	8.1 %	33rd
11	20	9.0 %	42nd
12	22	9.9 %	52nd
13	16	7.2 %	59th
14	7	3.1 %	62nd
15	21	9.4 %	71st
16	11	4.9 %	77th
17	13	5.8 %	82nd
18	8	3.6 %	86th
19	4	1.8 %	87th
20	28	12.6 %	100th

Table 17. Comparison of Mean Pull-up Scores with Research from cited Studies. All of the studies involving pull-ups were conducted with adult male samples. All participants were similarly instructed to perform as many consecutive pull-up repetitions as possible with-out allowing their feet to touch the ground.

Source	Description	Sample Size (N)	Mean No. Pull-ups	S.D.
Data set I (enlisted Marines)	Dead-hang Pull-ups Kip Pull-ups	223 223	12.848 17.437	4.412 3.028
Data set II (enlisted Marines)	Dead-hang Pull-ups Kip Pull-ups	430 312	12.900 16.795	4.645 4.311
Data set III (officer candidates)	Dead-hang Pull-ups Kip Pull-ups	200 162	16.040 18.562	3.591 2.945
Dupree (1961) (college students)	Pull-ups	15	7.86	4.04
Thomas (1970) (Air Force cadets)	Pull-ups	199	5.13	3.63
Singer (1970) (college students)	Pull-ups (pretest) Pull-ups (trained) Chin-ups (pretest) Chin-ups (trained)	28 28	8.00 12.57 8.21 12.21	3.61 4.58 3.23 4.09
Schmidt (1994) (Singaporean adults)	Pull-ups Chin-ups Vt. mod Pull-up	98	4.6 6.3 29.9	4.0 4.5 8.1
Robertson (1983) (Navy Seal trainees)	Pull-ups	1173	12.5	3.72
Grant et al (1996) (rock climbers)	Elite climbers Recreation climbers Non-climbers	10 10 10	16.2 3.9 3.0	7.2 9.0 3.9
Legg et al (1997) (elite world sailors)	Elite New Zealand Other Nations	25 85	12.8 10.4	3.7 5.9

adult male performs around 8 or less. Antinori et al. reported that the low efficiency of the pull-up exercise can be explained by considering that great muscle mass is required to contract isometrically in order to maintain the body center of gravity vertically aligned with the selected grasp on the horizontal bar. The confounding effects body weight and body-fat have on dead-hang pull-up performance is confirmed with the significant negative correlation coefficients shown in Table 8.

An analysis of the descriptive statistics for data sets 1 and 2 shows that since the implementation of the dead-hang pull-ups, Marine's PFT scores have decreased in all three events, not just pull-ups. The average run time has become about 21 to 36 seconds slower (a decrease of around 3 to 4 points), while the sit-up scores have decreased on average from 1 to 4 points. The decrease in performance for the run and sit-up tests supports the assumption that Marines are focusing more time and effort on the more difficult dead-hang pull-ups, and not as much time and effort on cardiovascular endurance. These results raise serious concern about the direction of the Marine Corps' efforts toward increasing overall physical fitness.

The lower left panel of Figure 10 (a) shows that the majority of individuals, in data set 1, who score 50 points or less on the pull-up test weigh over 160 lbs., with a large portion of those being over 70 inches tall. Comparing this panel with the top right panel of Figure 10 (a) reveals a subtle difference in the relationship between body size and pull-up scores greater than 80 points. The observation that the lowest pull-up scores tend to come from individuals with larger body sizes is confirmation that body weight confounds pull-up performance. The left panels of Figure 10 (b) show that individuals, from the OCS data (data set 3), who score less than 70 points on the pull-up test are fully capable of climbing a twenty-foot rope just as fast as those who score more than 80 points on the pull-up test. Figure 10 (c) shows that the majority of individuals, from the OCS data, who score less than 70 points on the pull-up test are fully capable of scoring 80 points or better on the obstacle course. An indication that the construct validity of the designed strength test for the PFT is flawed is given by the fact that over 41 percent of the individuals, in data set 3, scored from ten to fifty-four points less on the pull-up test than they did on the obstacle course.

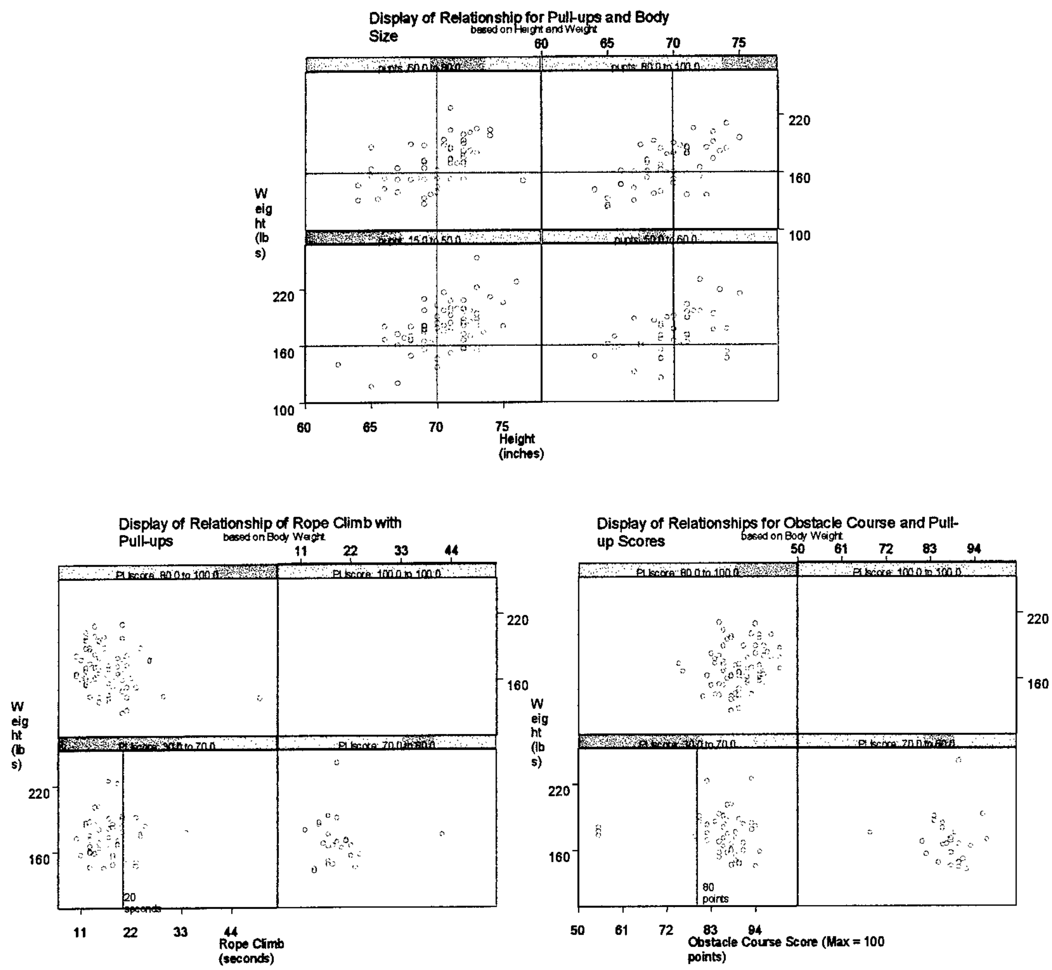


Figure 10. Relationships of Dead-hang Pull-ups with Height, Rope Climb, and Obstacle Course, based on Body Weight. The top figure (a) lower left panel indicates that the majority of Marines who score 50 or less points on the pull-up test are over 160 lbs. and 70 inches (data set 1). The lower left panels of the bottom displays (b and c) indicate that the majority of Marines who score 65 or less points on the pull-up test perform as well on the 20-ft rope climb, and obstacle course as Marines with higher pull-up scores (data set 3).

2. Analysis of Alternative Scoring Methods for the Dead-Hang Pull-Up

By comparing performance distributions and mean scores for the pull-up, sit-up, and run times, shown in Figure 11 and Figure 12, it is not surprising to see that the distributions are very different. The relevance of this observation is that since all three events are equally valued on 100-point scales it seems logical to expect that the average performance for each test should produce (roughly) similar mean scores, which is definitely not the case here. Both the pull-up and sit-up histograms indicate a ceiling effect at maximum performance levels, which is most significant in the sit-up distribution of scores. The box plots in Figure 13 show a more direct comparison of the PFT event scores. The median score for pull-ups is 60 points, while the run and sit-up median scores are 76.4 and 100 points respectively. The first and third quartile pull-up scores are 50 and 80 points respectively, while the respective first and third quartile scores for the run test are 67 and 86, and for the sit-up test 89 and 100 points. A small experiment was conducted on 88 individuals to estimate the first and third quartile scores for the new modified sit-up test, which was scheduled for implementation in July 1998. The first and third quartile scores for the modified sit-up are 76 and 100 points, while the mean score is 85.5 points and the median is 90 points. In comparison with the run and sit-up scores, Figure 13 shows that pull-ups have the lowest median and greatest inter-quartile range of scores, as well as the widest spread of points scored. As a result of its lower trend in scores, the pull-up event has the greatest influence on the overall PFT score of the three events.

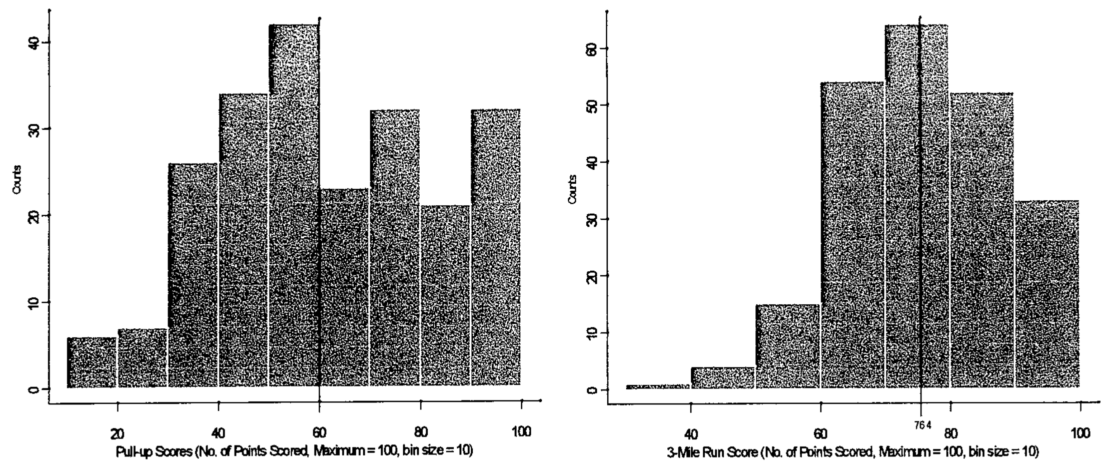


Figure 11. Histogram of Pull-Up Scores (data set 1). The Average Pull-Up Score = 60 points out of 100 points possible, which equates to the Median of 12 pull-ups performed, with the Mean = 12.85. Histogram of 3 Mile Run Scores (data set 1). Mean = 21.86 minutes for 76.4 points.

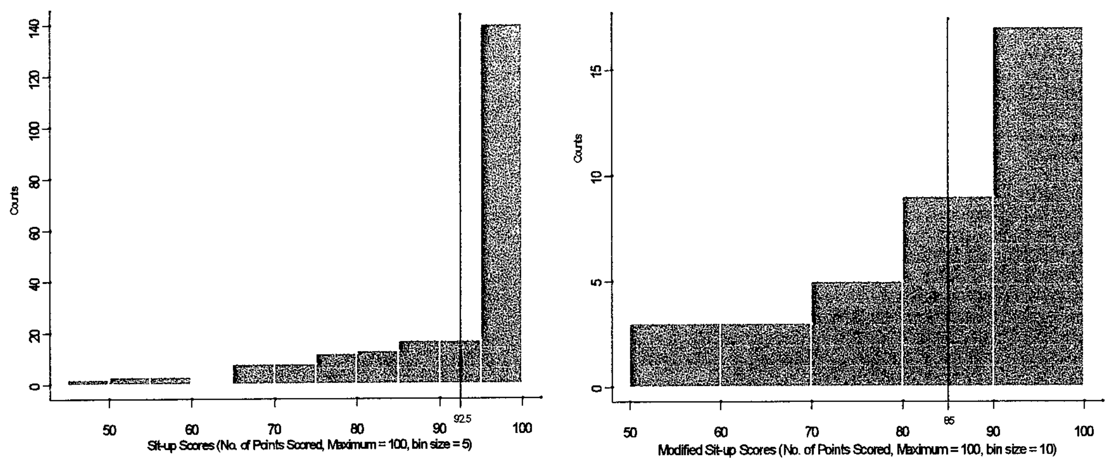


Figure 12. Histogram of Sit-Up Scores and Modified Sit-Up Scores. Current Sit-Up Mean = 76.13 for 92.5 points (data set 1). Modified Sit-Up Mean = 85.46 for 85 points (data set 4).

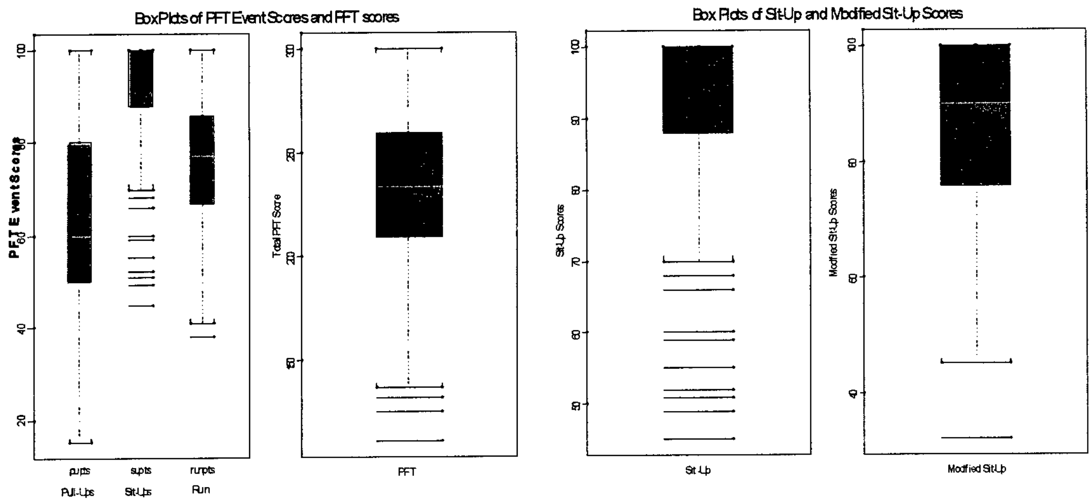


Figure 13. Box-plots of PFT Performance. The left most box-plot shows that pull-ups have the lowest and widest range of scores of the three PFT events. The PFT box-plot reveals an evident influence from the diverse pull-up scores. The right two plots compare the old and new sit-up test scores (data set 1).

The implementation of the modified sit-up test indicates a slight improvement toward equating the scoring distributions of the three equal valued PFT events, but an extreme ceiling effect remains apparent. According to a conversation with Lt.Col. Pappa concerning the three PFT events, Marine Corps officials are most satisfied with the scoring system for the run test and its resulting distribution. Since the run scores represented in Figure 11 appear the most normally distributed of the three PFT events, it is chosen as the basis for setting alternative scoring standards for the dead-hang pull-up test. Presented in Table 18 is the current pull-up scoring method compared with four of the five proposed scoring alternatives. The fifth alternative (not shown) simply scores the first ten pull-ups with seven points per repetition, and the last ten pull-ups with three points per repetition. The histograms shown in Figure 14 present the comparative

Table 18. Example Scaled Alternative Pull-up Scoring Systems.

Pull-up number	Current Pull-up value	Current Total Points	Option A Pull-up value	Option A Total Points	Option B Pull-up value	Option B Total Points	Option C Pull-up value	Option C Total Points	Option D Pull-up Value	Option D Total Points
1	5	5	8	8	8	8	8	8	7	7
2	5	10	8	16	8	16	8	16	7	14
3	5	15	8	24	8	24	8	24	7	21
4	5	20	8	32	8	32	8	32	7	28
5	5	25	8	40	8	40	8	40	7	35
6	5	30	5	45	5	45	6	46	6	41
7	5	35	5	50	5	50	6	52	6	47
8	5	40	5	55	5	55	6	58	6	53
9	5	45	5	60	5	60	6	64	6	59
10	5	50	5	65	5	65	6	70	6	65
11	5	55	5	70	4	69	4	74	4	69
12	5	60	5	75	4	73	4	78	4	73
13	5	65	5	80	4	77	4	82	4	77
14	5	70	5	85	4	81	4	86	4	81
15	5	75	5	90	4	85	4	90	4	85
16	5	80	2	92	3	88	2	92	3	88
17	5	85	2	94	3	91	2	94	3	91
18	5	90	2	96	3	94	2	96	3	94
19	5	95	2	98	3	97	2	98	3	97
20	5	100	2	100	3	100	2	100	3	100

distributions of the run scores with the pull-up scores and the five pull-up scoring alternatives (options A through E). Using a paired t-test to (separately) compare the run scores with each respective option, Table 19 shows that the p-values for the current pull-up and option D scores are significant, which indicates that their respective mean scores are not the same as the scores produced from the 3-mile run test. Option A produced the least significant p-value of 0.822 with a mean score of 76.18 compared to a similar mean run score of 76.43. Option E resulted in a high p-value of 0.619 with a mean of 75.91.

Table 19. Results of Paired t-Test Comparison of Run Scores vs. Proposed Pull-Up Scoring Alternatives.

PFT Scoring Option	Run	Current Pull-Ups	Option A Pull-Ups	Option B Pull-Ups	Option C Pull-Ups	Option D Pull-Ups	Option E Pull-Ups
Mean Scores	76.43	64.24	76.18	74.62	78.04	74.05	75.91
t-value		9.433	0.226	1.716	-1.540	2.168	0.498
p-value		0.000*	0.822	0.0876	0.125	0.031*	0.619

*Significant at $\alpha = 0.05$.

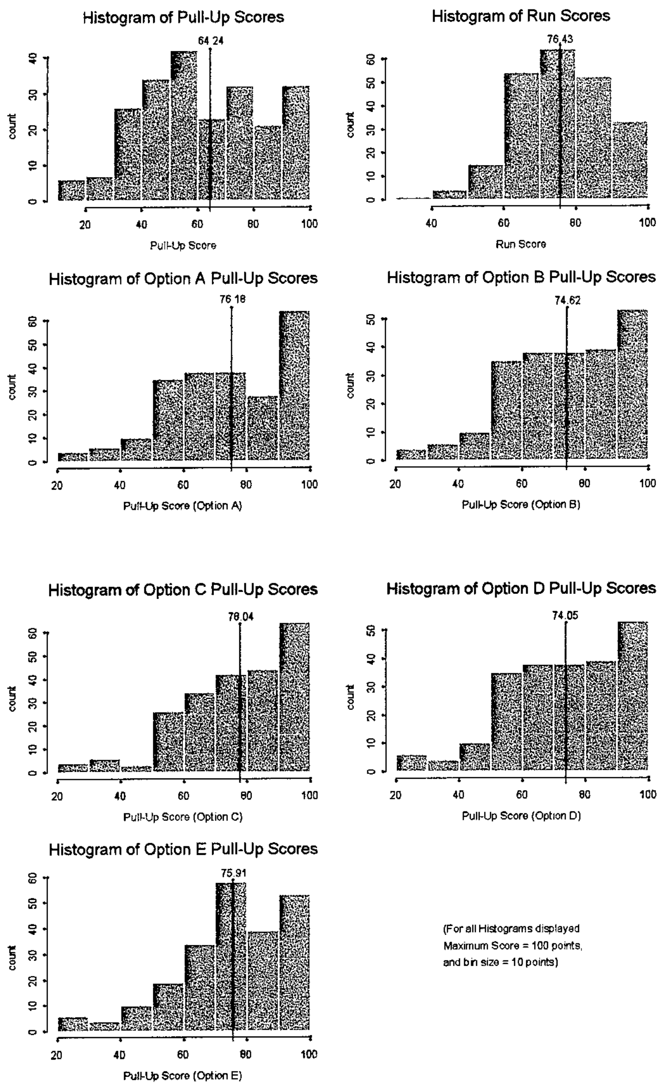


Figure 14. Histograms of Pull-up Scoring Options Compared with Run Scores. The top two diagrams reveal the diversity between the dead-hang pull-up and 3-mile run scores. Options A-E are an effort to increase the mean score for pull-ups to compensate for the negative influence pull-ups have on the PFT (data set 1). The respective bin sizes are based on 10 point intervals.

3. Analysis of Pull-Ups as a Valid Test of Muscular Strength and Endurance

A muscle does work when it produces a force (by moving a weight) over a distance. If the force (body weight) and the distance it is moved (arm length) is known, then the number of pull-ups performed determines the work performed and endurance potential. This quality is frequently reported in the standard units of work as foot-pounds or Newton meters. Muscular endurance is the ability to do muscular work. Muscular endurance is also an indicator of strength because of the level of output force required. The number of repetitions required to measure muscular endurance is a function of the strength of the muscles being used. To simplify this issue, muscular strength and endurance are related to body weight. A means to compensate for body weight confounding pull-up performance is to compute the total work done in the execution of pull-ups. To develop a general equation for the amount of work done, it is estimated from standard anthropometric data and the requirements of the test that the pull-up requires the body to be moved 20 percent of the height (M^{c}leod, Hunter, Ethison, 1983). Knowing the height and weight of the Marines being tested, the amount of work done per pull-up can be computed by multiplying the body weight by 20 percent of the height. With the formula shown below, the total amount of work produced is equal to the amount of work per pull-up times the number of pull-ups performed.

Total Work Done (ft.lbs.) = [No. of Pull-Ups Executed] x [Body Weight (lbs.)] x [Height (ft.) x 0.20].

The histogram of total work done for the pull-up test, shown in Figure 15, reveals a more normal distribution for pull-up performance than any other alternative (Figure 14). Total work performed and the resulting pull-up score for each option, from data set 1, is shown in Figure 16. As can be seen in each of the graphs, individuals perform over a wide range of total work (ft.lbs.) and still receive the same score for pull-ups. This is further indication of the confounding effect that weight has on pull-up scoring. To determine which pull-up scoring option best predicts total work done, linear regressions were conducted for the five respective models of 'work regressed on each option' with age, height, mass, and body-fat. The variable age is dropped from the models since its coefficient is insignificant (p-value > 0.05) for each. The coefficient for body-fat is not significant in the models with options A, C, and E. All models showed strong predictability with R-squared values greater than 0.94 (Table 20). Options B and D produced the largest R-squared values of 0.9719 and 0.9672 respectively.

To further investigate the validity of dead-hang pull-ups as a test of upper body strength and muscular endurance, analysis of the data collected from the Officer Candidate School (data set 3) was conducted. Although officer candidates do not necessarily represent the general population of the Marine Corps, results from their various physical fitness tests provide a unique opportunity to examine the relationship between pull-up performance and other upper body field tests for these individuals. Included in the analysis of data set 3 is a comparison of dead-hang pull-ups and the previously allowed kip pull-ups. Of the 206 samples in data set 3, only 145 samples have anthropometric measurements necessary to compute percentile body mass and percent body-fat. None of these 145 sample officer candidates exceeded the 60th percentile body mass for the general population, further indication that officer candidates are not a representative sample of the general population.

Table 20. Linear Regression Results for: Work Regressed on each Proposed Pull-Up Scoring Alternative with height, mass, and body-fat. The coefficient for body-fat is insignificant in the respective models with options A, C, and E. The respective R2 values for their adjusted models (without body-fat) are shown in parentheses.

Pull-Up Scoring Option	Option A Pull-Ups	Option B Pull-Ups	Option C Pull-Ups	Option D Pull-Ups	Option E Pull-Ups
t-value	25.723	26.940	24.840	26.840	25.083
p-value	0.000	0.000	0.000	0.000	0.000
R-Squared	0.9615 (0.9618)	0.9719	0.9478 (0.9479)	0.9672	0.9439 (0.9441)

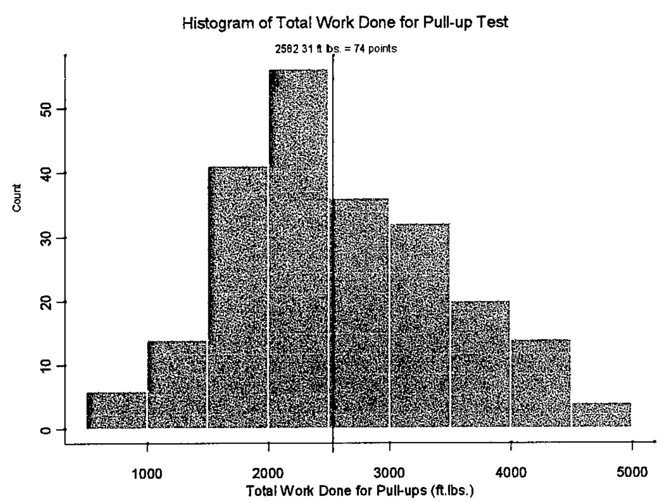


Figure 15. Histogram of Total Work Done for Pull-ups. Mean total work done is 2582.31 ft.lbs., standard deviation is 910.25 ft.lbs., Median is 2449.50 ft.lbs.. Using Appendix D-3 to convert to a corresponding 100 point scale: Mean = 74 points, standard deviation = 15, median = 72 points (data set 1, N = 223).

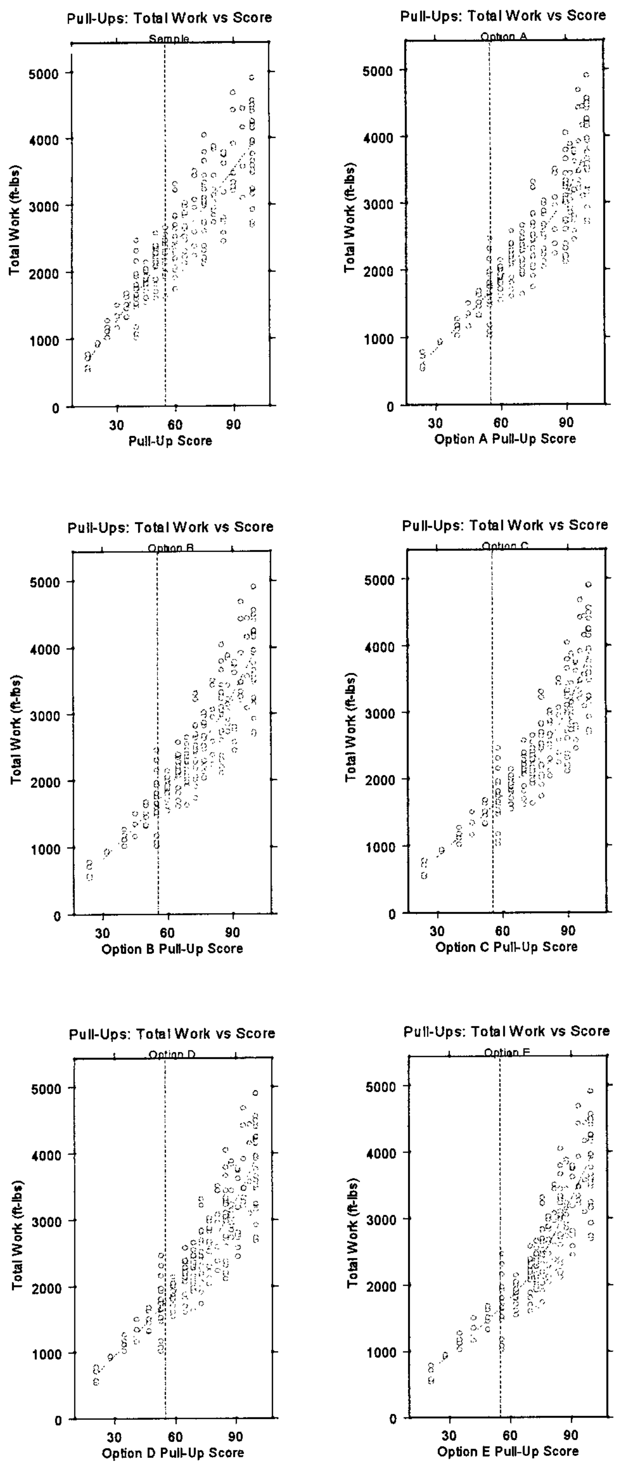


Figure 16. Scatter plots of Total Work Done vs. Pull-up Scoring Options A-E. The revelation of these diagrams is that it is possible to receive the same pull-up score (i.e., 58 points) for differing amounts of the actual amount of work done (1000-2500 ft.-lbs.). Note the differences in number of scores less than 58 points.

Correlation matrices were again evaluated to determine the relationship of the pull-up test with other field tests. The results for the officer candidate sample shown in Table 21 indicate a positive relationship exists between pull-ups and the PFT score, the obstacle course, and the endurance course. In an attempt to better capture the relationships between pull-ups and other upper-body field tests for those individuals who

Table 21. Pull-Up Correlation Coefficients with other Upper-Body Strength and Endurance Tests Based on Varying Ranges of Number of Pull-Ups Performed.

No. of Pull-Ups	1 to 20	1 to 10	11 to 15
Test	Pull-Ups	Pull-Ups	Pull-Ups
Total N	200	16	70
Critical R*	.138	.497	.232
Pull-ups	1.00	1.00	1.00
PFT pts	.811*	.418	.424*
O CRS	.325*	.431	.174
E CRS	.141*	.049	-.007
CCC	.072	.332	-.072
Pushups	.094	.084	.151
Rope Climb	.053	-.232	.091
Carry	-.108	-.245	-.125
F and M	.001	-.012	-.016
Combat Run	-.146*	-.171	.035

*Significant at $\alpha = 0.05$.

are most affected by the confounding effects of pull-ups, relationships for individuals with a lower number of pull-ups were investigated to see if any significant correlations exist. As suspected, the resulting coefficients indicate that the only significant relationships are between pull-ups and the PFT score, showing that a low number of repetitions on the pull-up test is not necessarily an indication of a similarly low score on other field tests of upper-body strength and endurance.

The results of a paired t-test comparison for both types of pull-ups vs. the obstacle course, the endurance course, and the combat conditioning course are shown in Table 22. Since all of these tests are on similar 100-point scales, and all are presumed to provide a test of upper-body strength and endurance, it seems reasonable to expect that they should produce similar scores. The results indicate that the only insignificant p-values (α = 0.05) for the t-test exist between kip pull-ups and the combat conditioning course, indicating that mean pull-up scores are not similar to mean scores for most upper-body field tests. In fact, the mean dead-hang pull-up score (80.2) for the officer candidates is lower in comparison to the mean scores of the other three field tests (87.4, 84.4, 95.0), while the mean kip pull-up score (92.8) is intermediate in comparison (89.5, 88.2, 94.3).

Of all the field tests conducted by the Marine Corps, it is the opinion of this analyst that the obstacle course should serve as the best measure of an individual's true upper body strength and muscular endurance. Thus, the obstacle course scores were compared with each of the five pull-up scoring alternatives using the paired t-test. Testing the null hypothesis H_o: $\mu_x = \mu_y$, Table 23 indicates that all the pull-up scoring options (except C) have similar mean scores in comparison with the obstacle course mean scores. Option B and option E are least significant with p-values of 0.6125 and 0.7541 respectively.

Table 22. Results of Paired t-Test Comparison for Pull-Ups vs. Other Upper Body Muscular Strength and Endurance Tests.

Test	Dead-Hang Pull-Ups	Obstacle CRS	Endurance CRS	Combat Conditioning CRS
Mean Scores	80.175	87.361	84.445	94.984
t-value		-5.617	-3.164	-10.902
p-value		0.0000*	0.0018*	0.0000*
Test	**Kip Pull-Ups**	**Obstacle CRS**	**Endurance CRS**	**Combat Conditioning CRS**
Mean Scores	92.809	89.496	88.184	94.250
t-value		3.878	4.479	-0.200
p-value		0.0002*	0.0000*	0.842

*Significant at α = 0.05.

Table 23. Results of Paired t-Test Comparison of Obstacle Course Score vs Proposed Pull-Up Scoring Alternatives (data set 3).

Test	Obstacle CRS	Current Pull-Ups	Option A Pull-Ups	Option B Pull-Ups	Option C Pull-Ups	Option D Pull-Ups	Option E Pull-Ups
Mean Scores	87.361	80.175	88.92	86.94	89.48	86.57	87.14
t-value		5.617	-1.500	0.507	-2.158	0.860	0.314
p-value		0.0000*	0.1354	0.6125	0.0322*	0.3907	0.7541

*Significant at α = 0.05.

According to the 'Guidebook for Marines' (Headquarters USMC, 1984) the obstacle course tests all four components of fitness (strength, endurance, agility, coordination), and thus should provide a good indication of a Marine's actual upper body strength and muscular endurance. Since the pull-up test is designed to test upper body strength and muscular endurance, it seems logical that the best method for scoring pull-ups is that which provides the closest relationship with performance on the obstacle course. As a means to determine which pull-up scoring option is the best indicator of this performance, both simple and multiple linear regression models were developed and compared. Table 24 lists the linear regression models to predict obstacle course performance based on the different pull-up scoring methods. Table 25 shows the comparison of the linear regression statistics for the obstacle course regressed on each of the seven pull-up scoring methods. Model Z1 represents the obstacle course regressed on the current pull-up scoring method. Models A1 through E1 represent the obstacle course regressed on each of the respective pull-up scoring options A through E, and model F1 represents the obstacle course regressed on the proposed score based on total work conducted by pull-ups.

For all the models shown in Table 24 and Table 25 the obstacle course score is the dependent variable (Y), while the different pull-up scoring methods are included as independent variables (X). The simple linear regression models take on the form: $Y_i = b_o + b_1X_1 + \varepsilon_i$ where b_o (the Y intercept) and b_1 (the slope of the regression line) are the unknown regression parameters and ε_i is a random error term. The results shown in

Table 25 reveal that model F1 is favored with the smallest RSE, the largest R^2, the smallest p-value, and the smallest RSS.

A similar comparison was conducted using multiple linear regression with three variable models. It is hoped that the additional independent variables will improve the ability to predict and reduce the unexplained variation. In this case the independent variables are height (X_2), mass (X_3), and the scoring method (X_1) represented in models Z2, and models A2 through F2. The results indicate that again model F2 is the favorable alternative with the best comparable regression statistics. The prevailing success of models F1 and models F2 indicates that the computed score of total work done for pull-ups provides the best indication of performance on the obstacle course. This result re-enforces the premise that the computation for total work done with the execution of pull-ups is the most fair and accurate measure of upper body strength and endurance explored in this study.

Table 24. List of Linear Regression Models used to Predict Performance on the Obstacle Course based on Different Pull-up Scoring Methods (data set 3).

MODEL NAME	LINEAR REGRESSION MODEL DEPENDENT MEASURE ~ INDEPENDENT VARIABLES
MODEL Z1	O'CRS score = current pull-up scoring method
MODEL A1	O'CRS score = pull-up scoring option A
MODEL B1	O'CRS score = pull-up scoring option B
MODEL C1	O'CRS score = pull-up scoring option C
MODEL D1	O'CRS score = pull-up scoring option D
MODEL E1	O'CRS score = pull-up scoring option E
MODEL F1	O'CRS score = pull-up scoring option F (Total Work)
MODEL Z2	O'CRS score = height + mass + current pull-up scoring method
MODEL A2	O'CRS score = height + mass + pull-up scoring option A
MODEL B2	O'CRS score = height + mass + pull-up scoring option B
MODEL C2	O'CRS score = height + mass + pull-up scoring option C
MODEL D2	O'CRS score = height + mass + pull-up scoring option D
MODEL E2	O'CRS score = height + mass + pull-up scoring option E
MODEL F2	O'CRS score = height + mass + pull-up scoring option F (Total Work)

Dependent variable = (regressed on) combination of independent variables.

Table 25. Comparison of Linear Regression Models to Assess the Best Pull-up Scoring Method to Predict Upper body Strength and Endurance as indicated by Performance Scores on the Obstacle Course (data set 3).

Regression Analysis of the Pull-up Option Models Regressed on the Obstacle Course Performance Scores.							
Compare Models Z1-F1	**Model Z1**	**Model A1**	**Model B1**	**Model C1**	**Model D1**	**Model E1**	**Model F1**
RSS	11959.56	12010.67	11957.60	12037.15	11998.00	12028.74	6086.50
RSE	7.955	7.972	7.954	7.981	7.968	7.978	6.547
R^2	0.06843	0.06445	0.0686	0.06239	0.06544	0.06304	0.13010
F-sign (p-val)	0.00026	0.00039	0.00025	0.00049	0.00035	0.00046	0.00000
Multiple Regression: Pull-up Option Models Regressed on the Obstacle Course Performance Scores.							
Compare Models Z2-F2	**Model Z2**	**Model A2**	**Model B2**	**Model C2**	**Model D2**	**Model E2**	**Model F2**
RSS	5965.76	5936.21	5926.09	5977.08	5967.21	6010.39	5865.54
RSE	6.528	6.512	6.506	6.534	6.529	6.552	6.473
R^2	0.14740	0.15160	0.15300	0.14570	0.14720	0.14100	0.1617
F-sign (p-val)	0.00005	0.00004	0.00003	0.00006	0.00005	0.00009	0.00002

F1 adjusted $R^2 = 0.12550$, F2 adjusted $R^2 = 0.14374$ ($b_1 = -.12$, $b_2 = -.83$, $b_3 = .25$).

Figure H-4 in Appendix H shows diagnostic plots for the regression of obstacle course scores on work done in pull-ups, height and body mass for the OCS data. These portray behavior very similar to that discussed earlier for Figures H-1 through H-3. Again this data set appears to have several outliers (relative to the model used), all of which are apparent in the various plots. The four extreme outliers identified in this model are all associated with low obstacle course scores of 55 points, which is the score given candidates who fail to negotiate all the obstacles on the course.

C. ANALYSIS OF PHYSICAL FITNESS TEST ALTERNATIVES

The ultimate aim of this thesis is to provide the Marine Corps with a more accurate instrument to measure physical fitness. So, it is important to know which aspects of fitness are most relevant for Marines. An infantry officer who has trained Marines for the rigors of combat understands that stamina is justly regarded as the most important aspect of fitness for Marines. Stamina is a combination of muscular and cardiovascular endurance. Muscular endurance, which is closely associated with cardiovascular endurance, is that physical characteristic that will allow prolonged activity of a moderate tempo. The endurance course conducted by the officer candidates in this study is an excellent test of stamina and muscular endurance, and thus provides a solid measuring instrument for the overall physical fitness levels of Marines.

A proposed 3-profile PFT comprised of aerobic, muscular, and body-fat profiles was derived from a 5-profile model presented in the book 'Exercise Prescription for Fitness' by Reid and Thomson. Reid and Thomson (1985) developed a 5-profile model comprised of an aerobic profile, a muscular profile, a flexibility profile, a posture profile, and a body-fat profile. The evaluation of their aerobic profile requires the completion of one of four standardized tests (12 minute run, 3-minute step-up, bicycle ergometer test, or a timed tread-mill test). All four standardized tests provide a means to determine a score (based on percentile performance levels) for maximal oxygen consumption. Their muscular profile consists of three muscular endurance tests (chin-ups, sit-ups, and push-ups), and two muscular strength tests (hand-grip strength, and leg-lift strength). The muscular strength tests require equipment that is not readily available for practical testing of Marines. All test scores are based on corresponding percentile rankings. The average of the five scores provides a mean rating for muscular endurance and strength. The body-fat profile is assessed via anthropometric measurements to assess optimal body mass, and skin-fold measures with calipers to assess body-fat. The corresponding profile score is also based on percentile ranking.

The flexibility and posture profiles used by Reid and Thomson are considered irrelevant for purposes of the Marine Corps' evaluation of fitness due to the assumption that they are inherent requirements of the other three profiles, as well as being potentially ambiguous and subjective measures. The overall fitness score is calculated by multiplying each of the profile scores by a given profile-weighting component, and totaling the resulting weighted scores. Note that not all the profile areas are weighted equally. For example, aerobic fitness is regarded as the most important aspect of fitness and thus is given the greatest weighting (0.30) (Reid, & Thomson, 1985). They weighted the body-fat profile with (0.25), and the remaining three profiles equally at 0.15. Their book suggests that all of these profiles should be addressed. However, since the Marine Corps currently has the capability to feasibly measure 3 of the 5-profiles (with modification). The 3-profile PFT proposal was derived from the 5-profile model, and simplified to accommodate the needs of the Marine Corps.

It is suggested that the current 3-mile run is an appropriate aerobic measure to represent performance in-lieu of the four options proposed by Reid and Thomson, because of its wide range of application and acceptance around the Marine Corps. The suggested muscular profile is measured by a combination of the pull-up, sit-up and push-up scores, while the body fat profile is provided by a scoring method proposed by Reid and Thomson. The suggested weights to be applied to these three components are 40% aerobic, 35% muscular and 25% body fat. The Marine Corps defines its physical fitness objective as attaining a healthy body that can remain effective in prolonged activity even when it is necessary to endure discomforts and environmental stress for lengthy periods. Therefore stamina, a combination of muscular and cardiovascular endurance, is considered the most important element in Marine fitness, which is consistent with Reid and Thomson's regard for aerobic fitness as the most important aspect of fitness. As a starting point in establishing the profile-weighting components for the proposed 3-profile PFT, body-fat was held at 25% of the overall fitness score. For Marine Corps purposes it is assumed that the muscular profile inherently/indirectly captures most of the fitness aspects intended by the flexibility and posture profiles. The 30% remaining after the elimination of the posture and flexibility profiles were thus re-distributed to the aerobic (10%), and muscular profile (20%) commensurate with the inherent relationships assumed between the outgoing and remaining profiles. This was done in such a way as to ensure that the total aerobic profile weight (40%) would carry proportionally more weight than the muscular profile weight (35%), and the body-fat profile weight (25%).

To investigate rational ways of measuring pull-up performance for the muscular profile, several regression models were employed with data set 3 (OCS). Recall that the data available includes scores made by these individuals on both the obstacle course and the endurance course, the two tests judged most indicative of muscular strength and endurance. The observed scores on each of these courses, for the officer candidates (data set 3), were regressed on the PFT score achieved, using 7 different options for scoring the pull-up performance (current method plus the 6 alternatives already mentioned). For both cases (obstacle and endurance) pull-up scoring method F, using work performed rather than simply the number of pull-ups, gave the best fitting model; pull-up scoring by work performed is a better predictor of obstacle and endurance course scores than the others considered.

In addition, for this same data set, the two course scores were each regressed on the PFT score (again 7 different methods for scoring pull-ups) plus the individuals percent B.F.; again for both course scores the work-performed measure of pull-ups produced the best fitting model. Thus, it is suggested that pull-ups be scored by the work performed.

A proposed 3-profile PFT score sheet is shown in Figure 17. The proposed aerobic profile is simply the current run test, but is appropriately worth forty percent of the overall fitness evaluation, because it is commonly accepted as the most important aspect of fitness (Reid, & Thomson, 1985). The 3-profile PFT alternative will provide a broader evaluation for muscular strength and endurance with 3 tests contributing the muscular profile (pull-ups, push-ups, and sit-ups). Appendix E, the U.S. Army push-up scoring standards, was used in computing the respective push-up scores for the officer candidates comprising data set 3. The corresponding scores recommended by Reid and Thomson for body-fat percentages based on respective age groups are presented in Appendix C.

Proposed Physical Fitness Testing (PFT) Alternative. Maximum Score Possible = 300 points.			
Profiles Ranked by Importance:	**Profile Score (100 point maximum)**	**Profile Weighting Component**	**Weighted Profile Score**
1. Aerobic Profile	**Run score = ______**	**X 1.20** [40% weight of 3 profiles]	= ____________
2. Muscular Profile **sit-up score =______** **pull-up score =_____** **push-up score =_____**	**Mean Muscular Profile Score = __________**	**X 1.05** [35% weight of 3 profiles]	= ____________
3. Body-Fat Profile **Percent B.F. = _____**	**pBF Percentile Score =** **________________**	**X 0.75** [25% weight of 3 profiles]	= ____________
A. Total PFT Score			= ____________

Figure 17. Proposed 3-Profile PFT Score Sheet. The Aerobic profile is the 3-mile run test with a 40% weighting. The Muscular profile combines the modified sit-up, the prefered pull-up method (Appendix D for Total Work Done, or Table 18 for option B), and the push-up (Appendix E) into a mean score. The muscular profile has a 35% weighting. The percent body-fat is obtained from Appendix B, and converted to a percentile score using Appendix C. The body-fat profile has a 25% weighting.

To illustrate the scoring procedure proposed with the 3-profile PFT suppose that the fitness scores shown below were obtained from a 26 year old Marine who is 69 inches tall, weighs 184 pounds, and has 14.5 percent body-fat. The first step is to conduct the test, and collect the fitness/performance values for each profile.

3-mile run time (min:sec)	= 22:00
number of sit-ups	= 85
number of push-ups	= 65
number of pull-ups	= 12
body-fat percentage	= 14.5

The second step in computing the overall fitness score is to assess the appropriate profile score based on the given fitness values for each profile.

Aerobic Profile:	**76 points**	(Table 1; CMC, 1988; for 22 min run time)
Muscular Profile:		
Sit-ups:	85 points	(ALMAR 213, 1996; 85 sit-ups at 1 pt. ea.)
Push-ups:	85 points	(Appendix F; 65 push-ups, 22-26 yr. old)
Pull-up (Work):	212 ft.lbs.	(Appendix D-1, 69 inches and 184 lbs.)
Total Work Done:	2544 ft.lbs.	(Appendix D-2, 12 pu's at 212 ft.lbs. each)
Pull-ups:	74 points	(Appendix D-3, for 2544 ft.lbs. of work)
Muscular Profile:	**81.33 points**	(Mean Score = [85 + 85 + 74]/3)
Body-Fat Profile:	**75 points**	(Appendix C; 26 year old with 14.5 pBF)

To obtain the corresponding score for percent body-fat read down the appropriate column for a 26 year old male until reaching the value in which his body-fat is less than or equal to a listed limit. Read across that row to the corresponding body-fat score in the center column. The third step is to compute the weighted score for each profile by multiplying each profile score by the given profile-weighting component.

Aerobic Profile:	76 X (1.20) = **91.2 points**
Muscular Profile:	81.33 X (1.05) = **85.4 points**
Body-Fat Profile:	75 X (0.75) = **56.25 points**

Finally, total the weighted scores to obtain an overall fitness score of **232.8 points** for a respectable first class PFT score. It should be noted that using the option B scoring method (Table 18) for the dead-hang pull-ups, instead of the computation for work, results in a similar score of **232.5 points**. However, the current scoring standards for the same Marine with the same average test scores would result in a **221 point** PFT (76 for run, 85 for sit-ups, and 60 for pull-ups), which is a second class score for this 26 year old. Figure 18 shows a sample histogram of body-fat distribution scores (data set 1) using the proposed body-fat scoring table in Appendix C. Although the histogram indicates a ceiling effect (many scores between 90 and 100 points), the mean score is a reasonable 75.4 points. This value is comparable to the expected mean scores for the run and pull-up tests (assuming pull-ups are scored using the work computation, or option B), and not as steep as the new sit-up distribution.

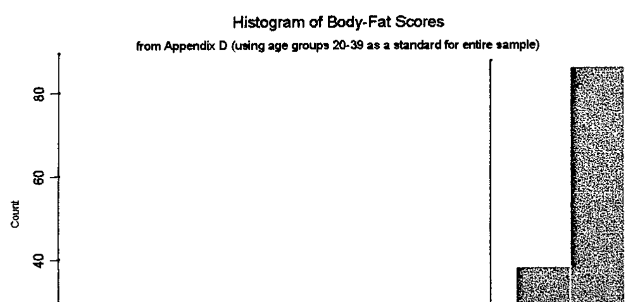


Figure 18. Histogram of Proposed Body-Fat Scores. Shows an example of corresponding scores for body-fat using the table provided in Appendix C. The column labeled 'Male ages 20-29 and 30 to 39' are suggested to apply to encompass all the Marines from data set 1 (Marines younger or older than this age group were scored with respect to the closest respective age group).

It is wise to recall that regression analyses provide measures of association between variables. Such analyses, by themselves, do not imply that any necessary causal effects are present. The results of this study do show that there is definitely room for improvement and flexibility in accurately assessing the physical fitness levels of Marines with such instruments as a rudimentary PFT.

IV. DISCUSSION

A. BODY WEIGHT AND BODY-FAT

The Defense Department guidance which prompted the major shift in focus of the current Marine Corps weight control program from body weight to body-fat is an important improvement. The results of this study and the supporting research indicate that body-fat has greater influence on physical performance than body weight. The results shown in Table 11 and Figure 5 further support Rupinski's findings that body weight is not a preferred measure for predicting body-fat. Similarly, standards based on weight or body masses are deficient in that they cannot distinguish between persons who are overweight due to highly developed muscles and those overweight due to excessive fat. The Marine Corps uses the body-fat measures as a second order criteria in an attempt to make this distinction. Currently, Marines who exceed the maximum weight standards are then subjected to the body-fat standards. If they exceed both the maximum weight and body-fat standards, they must participate in a weight control program. Failure in the weight control program can lead to separation from the Marine Corps. According to results found in this study, almost a quarter of the 223 Marines sampled exceeded the body-fat standards. Only about 31 percent of the Marines who exceeded the body-fat standards would be successfully identified for a weight control program under the current system. Surprisingly, the remaining 69 percent of the Marines who exceeded the body-fat standards weighed in under their limit, which is further support that the 18 percent body-fat limit is set too low.

The Marine Corps' height-weight and fat policies have been under fire for years. With the recent implementation of the latest policy changes, the complaints have been so widespread that the Marine Corps' Inspector General is investigating the accuracy of the "fat estimation" tables. The results of the unpublished pilot survey conducted in support of this study (see Appendix F) indicate that a significantly large portion of this sample does not feel that the current Marine Corps fitness standards are fair/valid for all Marines. According to the current policy, the findings from the data set 1 analysis indicate that 51 Marines, from the 223 in the sample, are candidates for automatic adverse reports for exceeding 18 percent B.F. The dangerous flaw in automatically issuing this number of potential career damaging adverse reports is that 25 of these 51 Marines are qualified with first class PFT scores, and none of them failed!

1. Weight and Body Mass

According to Rupinski, if the Marine Corps incorporated its body-fat standards into its height-weight standards, the eligible male population would dramatically decrease. The incorporation of the 18 percent B.F. standard as a base for establishing weight limits means that the maximum allowable weights would be even lower than they are. This dramatic decrease in the eligible male population indicates that a problematic error exists in the establishment of the body composition standards. These results further suggest that the Marine Corps should consider adjusting both standards accordingly and focus on semi-annual body-fat measures rather than weigh-ins.

The National Institute of Health (NIH) convened a conference on the health implications of obesity in 1985. Rupinski reported that during this conference a committee of medical professionals recommended weight reduction for persons with body weights 20 percent or more above desirable levels. In terms of body mass, these standards are quite similar to the overweight standards developed by the NCHS in Table 3. The current Marine Corps' standards are actually stricter than the NCHS overweight standards (85^{th} percentile) with percentiles ranging from 82 to 84.

To be classified as first class on the PFT, the minimum scores are shown in Table 2. Using results from predicted PFT scores at the proposed 85^{th} percentile, the typical Marine at the maximum weight would likely be categorized as first class on the PFT. The regression analysis demonstrated that PFT scores tend to decrease with increases in body mass or weight. The decrease in PFT scores with respect to larger body masses justifies the use of a maximum weight standard. If a first class PFT score is desired for Marines, setting maximum weight limits with respect to the 85^{th} percentile body mass is an acceptable alternative. In fact, according to the regression analyses, and contingency table results, the Marine Corps could justify adopting the less restrictive DoD weight standards without significantly decreasing PFT classification scores.

2. Percent Body-Fat

No other institution takes the problem of body-fat more seriously than the Marine Corps. The Corps insists on a lean physique for the following reasons: to reduce risk of incurring major health problems; to dramatically improve function, agility, efficiency, strength and endurance; and to maintain the Marines' traditional pride in appearance. Although physical fitness is not perfectly related to either body-fat estimates or weight-height measures, percent body-fat estimates predicted performance on the PFT better than weight-height indices. Percent body-fat estimated from circumference measures was a better predictor of PFT performance than were any of the weight-height indices.

Estimates of percent body-fat from circumference measures may be better predictors of physical fitness because they are more reliable estimates of actual body-fat than weight-height measures (Hodgdon, 1987; Pollock & Jackson, 1984). If fat is the most important underlying factor limiting physical work capacity and fitness, then a reliable body-fat measure should be more strongly associated with specific tests of physical fitness.

Dr. Hodgdon's percent body-fat tables are based on predictive equations, which were originally developed for the Navy with a sample population of Navy personnel. Hodgdon determined the best least-squares fit equation for men produced an R^2-value of 0.887, and a standard error of measure of 3.20 percent fat. According to MCO 6100.10A, the average body-fat for male Marines is around 16.5 percent. With a maximum 18 percent body-fat limit given the above measure of error and mean fat content, it is easily apparent how rigid and restrictive the standard actually is. With this level of variability it is not unreasonable that an average Marine having 16.5 percent B.F. with a standard error of 3.2 percent B.F. could easily be measured at 19.7 percent B.F. and could erroneously be identified as over-fat. Many commanders have acknowledged that without the option of weight waivers (the new policy) they have no choice but to put overweight or over-fat Marines on a remedial program and discharge those who don't meet the standards. More startling is that a few commanders have reported the dilemma of identifying over-fat individuals within their commands who are top Marines with top PFT scores. Fuentes has reported that some Marines are resorting to drastic measures to try to save their careers. The automatic adverse fitness report for Marines whose fat estimate exceeds 18 percent can be devastating and career ending. Marines have reportedly tried to drop dangerous amounts of weight in the week prior to their PFT weigh-ins by fasting, taking longer runs, conducting more rigorous physical training, and by sweating in the sauna. These methods are not only a dangerous drain on energy needed for the PFT, but they are also extremely unhealthy.

It is paramount that the person to whom the equation is applied is 'like' the sample population upon which the predictive equation was developed. Thus, Dr. Hodgdon is currently conducting a validation study for the Marine Corps with a sample population of Marines. The regression analysis conducted in this study demonstrated that PFT scores tend to decrease with increases in body-fat. The decrease in PFT scores with respect to larger body-fat justifies the need for a maximum percent body-fat requirement. If a first class PFT score is the desired standard for Marines, then the contingency table results have shown that setting the maximum body-fat limit at 20 percent is an acceptable alternative. Additionally, the regression analysis which examined alternative body-fat levels based on obtaining a first class PFT performance suggests that a 20 percent body-fat limit is acceptable for Marines over 26 years old. However, a comparable regression analysis that incorporated the prevailing pull-up scoring alternative (using 'Total Work Done') within the PFT score has shown that a 20 percent body-fat limit is an acceptable alternative for all age groups with respect to obtaining first class PFT scores. Thus, a Marine Corps relaxation of the current body-fat standards to a proposed maximum acceptable limit of 20 percent would not lead to significant decreases in physical fitness performance.

B. DEAD-HANG PULL-UP

1. Validity of Pull-up Test

The Marine Corps uses the pull-up test because upper body pulling has definite application to combat related movements (getting over obstacles, pulling objects or people, or hanging onto an overhead object). However, it is not evident that the pull-up is a valid measure of absolute muscular strength or muscular endurance. Based on the results of this study and others like it, there are good reasons to view the validity of such a field test as problematic. First, it seems likely that performance is confounded by body weight, the resistance overcome in performing these tests. Second, it has an overwhelming influence on the PFT score in comparison with the sit-up and run tests. Third, it does not have any consistently significant relationship with other field tests (obstacle course, combat conditioning course or rope climb) that require upper body strength and muscular endurance. In general, results from this study reveal low validity coefficients between pull-ups and field tests requiring muscular strength and endurance. The pull-up was intended to test a Marine's ability to manipulate his own body weight. This concept may be flawed since the rigid design of the dead-hang pull-up does not allow Marines to 'adapt, improvise and overcome' the chip-up bar as they would when negotiating obstacles in combat, or on the obstacle course. The obstacle course is the best indication of a Marine's ability to manipulate his own body weight in negotiating combat type obstacles. The fact that over 41 percent of the officer candidates scored from ten to fifty-four points better on the obstacle course than they did on the pull-up test is an indication of the flaw in the construct validity of the designed strength test for the PFT. The results of this study indicate that body weight is a major confounder of performance on the pull-up test. Total body weight was assumed synonymous with the effective force exerted, although it is recognized that the weight of the forearm is not moved through a vertical distance. The confounding effect of body weight as observed in this study is consistent with results from previously published studies (Pate et al., 1993; Fleishman, 1964; Cureton et al., 1975; Engelman & Morrow, 1991). This indicates that the dead-hang pull-up does not exhibit concurrent validity as a test measure of upper body strength and muscular endurance.

The Marine Corps' originally only required 18 dead-hang pull-ups to score 100 points. Apparently the number required to max the PFT was raised to 20 when kipping became acceptable. Now that the requirements have returned to the stricter dead-hang technique, the Marine Corps has shown no indication of returning the maximum repetitions required to 18.

2. Proposed Alternatives for Testing Upper Body Strength and Muscular Endurance.

a) The Push-up is an Alternative Test of Upper Body Fitness.

The Marine Corps is not alone in facing the problem of assessment of upper body strength. Pate et al. (1993) indicated in their research on the Validity of Field Tests of Upper Body Muscular Strength that as fewer and fewer teenagers can perform a pull-up, there is a trend toward testing upper body pushing strength as a substitute. The push-up has been used in the past as part of the Marine Corps PFT. The reintroduction of push-ups has some relevancy. Since the push-up tests different muscles than those employed in the pull-up, the inclusion of both tests complement each other as a combined test of overall upper body strength and muscular endurance.

The push-up, a mainstay in maintaining Marine fitness, is an important element of every unit's daily-seven workout program. The push-up can easily be performed anywhere: on a flight deck, in the aisle of a transport plane, at U.S. embassies and around the globe. Rupinski reported that correlation coefficients for push-ups and pull-ups with a given task are virtually identical, implying that the Marine Corps could substitute a push-up test for the pull-up test without changing the basic meaning of the test. This finding is further supported by the high correlation coefficient (0.82) between push-ups and pull-ups (Rupinski, April 1989). The push-up scoring standards utilized by the U.S. Army are shown in Appendix E. The Marine Corps could easily adopt the Army's overall scoring system or justify one standard for all age groups. In whichever manner it may be decided to incorporate the push-up test into the PFT (as a substitute, or a complement to the pull-ups), it is suggested the Marine Corps adopt the Army's 22 to 26 year old age group standards for all Marines.

b) Modified Pull-ups

Many modified pull-up tests have been developed for measuring the upper body strength and muscular endurance component of physical fitness. The New York Modified Pull-ups introduced by the New York State Education Department, the Vermont Modified Pull-ups validated by Pate et al.(1993), and the NCYFS II Modified Pull-up test analyzed by Cotton are a few examples of efforts that have been made toward developing a valid upper body strength and muscular endurance field test. The New York and Vermont Modified Pull-ups allow the subject's heels to rest on the ground, while the subject pulls his body up to a horizontal bar adjusted to height. The NCYFS II Modified Pull-ups do not allow the subject's heels to rest on the ground, and like the Vermont Modified Pull-up it only requires the subject to pull-up until his chin is above an elastic band positioned about 6 inches below the horizontal bar. Reid et al. (1985) state in their Exercise Prescription for fitness that the number of pull-ups recorded is the number completed plus the number of half pull-ups (i.e., when the elbow flexion reaches 90 degrees). The Marine Corps' version of a modified pull-up is the previously authorized kip pull-up, which allowed subjects to swing their bodies in an effort to negate the confounding effect of lifting their bodies vertically as a dead weight. The results of this and other studies indicate that modified pull-ups, although slightly weight dependent, are significantly less weight dependent than the dead-hang pull-ups, and more reliable as predictors of upper body strength and muscular endurance.

c) Total Work Done with Pull-ups

The development of a method to measure total work done in the pull-ups is significant in two ways. First, the amount of work done, or work output, is necessary to determine human efficiency in doing pull-ups. As such, this method may lead to further research in the continuing effort to evaluate strength, endurance, and coordination. Second, if physical fitness is defined as work capacity, then this method is a valid criterion in the development of tests of physical fitness. Tables assessing the corresponding scores for pull-ups are presented in Appendix D-1 through D-3.

The results indicated that the total work done in pull-ups might provide compensation for the confounding relationship between body weight and pull-ups. There is a significant negative relationship between body weight and the number of pull-ups. This suggests that in physical fitness measurement, where physical fitness is defined as work capacity, the heavier Marine may actually be doing as much physical work as the lighter Marine even though the lighter Marine may do considerably more pull-ups.

C. PROPOSED 3-PROFILE PFT

Marine standards have maintained the Corps' reputation as the nation's elite force for over 200 years. The objective in the design of the PFT was to produce efficient field tests that would not require professional oversight. Understanding now that the dead-hang pull-up test is indeed problematic, and that body-fat percentage has a tremendous influence on physical fitness, the Marine Corps has an opportunity to improve upon the current standards. A Marine Corps paradigm shift is proposed with the alternative 3-profile PFT.

Aerobic endurance attained through distance running provides definite health benefits. A Marine with increased aerobic fitness will likely have lower resting heart rate, reduced cardiovascular disease, improved weight control, and the enhanced ability to hike farther with a heavier load. The 3-profile PFT alternative attempts to capture a better measure of upper body strength and endurance, includes a score for body-fat, and prioritizes the value of each scored test based upon its influence on overall physical fitness (Reid, & Thomson , 1985).

The 3-profile PFT alternative will provide a broader evaluation for muscular strength and endurance with 3 tests in the muscular profile, and it requires the inclusion of body-fat as a graded part of the test. Finally, the proposal proportions test scores based on the importance/influence on overall physical fitness. The regressions conducted in this study to model the obstacle and endurance courses have demonstrated that cardiovascular endurance is the most influential test of overall fitness (with regard to the strong relationship the courses have with the run test). This assessment is consistent with Reid and Thomson's 5-profile model allocating the aerobic profile with the greatest value. The recommended pull-up scoring option accounts for the total work done, while option B is the preferred scoring alternative. The sit-up score will come from the modified sit-up test, while the push-up score can easily be assessed from the Army standards shown in Appendix E. Appendix C is the table used to establish scores for respective body-fat percentages.

V. CONCLUSIONS

A. IMPROVEMENTS FOR THE MARINE CORPS FITNESS STANDARDS /EVALUATIONS

The Defense Department is initiating a new program to improve the physical fitness of its people: "Operation Be Fit." Secretary of Defense William Cohen has recently directed the services to review and toughen their physical fitness standards. The Secretary said he doesn't want any more exceptions granted to service members unwilling to get in the "best possible physical condition (Cohen, 1998)."

> We have to produce fit, disciplined, motivated soldiers, sailors, airmen, and marines. We must pay special attention to physical fitness. We need to provide realistic and challenging field exercises that are instructive and push individuals to achieve their maximum potential, so I'm directing the services to reevaluate and to toughen the training and physical fitness standards... What we want to do is produce fit, physically capable, and well-disciplined troops. To the extent that they need to enhance those physical requirements, I strongly endorse that (Cohen, 1998).

In keeping with the Secretary of Defense's guidance and within the limits of this study, the following conclusions were drawn:

1. Body weight has a slight negative relationship with physical fitness performance, thus justifying the need for maximum weight limits. This study has demonstrated that the Marine Corps could adjust its maximum weight limits to correspond with the 85th percentile body mass for given heights without any decreases in PFT qualification scores.
2. Excess body weight and body mass are not reliable indicators for identifying the majority of the over-fat Marine population who exceed the prescribed

percent body-fat standards. Body-fat has been shown to have a greater negative influence on PFT performance than does body weight or body mass. Therefore, the Marine Corps would greatly benefit by incorporating the percent body-fat measure in lieu of (or in addition to) the semi-annual weigh-in for the PFT.

3. Body-fat bears a strong inverse relationship to physical fitness performance, thus justifying the need for a maximum percent body-fat limit. This study has demonstrated that the Marine Corps could adjust to a maximum 20 percent body-fat limit without causing any significant decreases in PFT qualification scores.

4. The pull-up test is confounded by weight and has not been validated as a true measure of upper body strength and muscular endurance. The current pull-up scoring system produces a negative skewing effect on the overall PFT scores. The Marine Corps has several alternatives to improve upon the validity of a measure of upper body strength and endurance, all of which would be an improvement over the current pull-up scoring method. The following options are proposed for consideration by Marine Corps' decision-makers in increasing order of preference.

   a. The kip modified pull-up: has less confounding effect due to weight than dead-hang pull-ups; has an increased overall PFT score; has positive relationships with other upper body strength and muscular endurance field tests. Although an improvement from the negative aspects of the dead-hang pull-up, the resulting positive skewing effect due to the modified pull-up (the kip method tends to produce very high scores) indicates a trend toward artificially inflating test scores. This would be the simplest change to incorporate of all the scoring alternatives.

b. Push-ups could be substituted as an alternative upper-body strength and muscular endurance field test for pull-ups.

c. For the simple re-scaled pull-up scoring options A through E, options A, B, and E have been shown to be consistent in that they negate the confounding effect of weight on pull-ups; do not have a negative skewing effect on the overall PFT score; have comparable mean scores with the run. Each of the three scoring options (A, B, or E) would provide justifiable compensation toward improving the negative effects of the dead-hang pull-up. Pull-up scoring option B is the preferred alternative to provide an improved estimate of upper body fitness followed, by option E for simplicity.

d. The computation of Total Work Done with pull-ups has eliminated the negative confounding effect of weight on pull-ups; resulted in the most normal distribution of all pull-up scoring alternatives; established the strongest positive relationship with other upper body strength and muscular endurance field tests. Using height, weight and number of pull-ups to compute Total Work Done, and converting that value to a corresponding score is easily accomplished with the tables in Appendices

D1 through D3. This alternative is the most extreme and complicated change of all the pull-up scoring options. Yet, this represents the most valid and accurate measure of upper body strength and muscular endurance of all the pull-up scoring options.

e. The Marine Corps' best alternative is the proposed muscular profile option, which includes a combined mean score for pull-ups, sit-ups, and push-ups into a single PFT category (muscular profile). The muscular profile option eliminates the likelihood of any confounding by weight since the computation for work takes body size into account, and thus eliminates the negative skewing of the overall PFT scores. The three test muscular profile has the strongest likelihood of producing a true measure of muscular strength and endurance. If Marine Corps' decision-makers do not choose to adopt the muscular profile, or the Total Work Done methods, then the preferred scoring alternatives for pull-ups are option B followed by option E and then A.

5. To accommodate Marines stationed around the world, the 3-profile PFT alternative is designed for use in virtually any environment. Given the influence body-fat has on fitness performance, the Marine Corps could improve and at the same time toughen its fitness evaluation with the inclusion of the measure of body-fat as the third profile of the PFT score. This concept adds incentive for individuals to maintain prescribed standards of fitness, with those having lower percentages of body-fat being justly rewarded with higher

scores. Incentive to decrease body-fat is likely to improve the overall fitness of the Marine Corps. The 3-profile PFT alternative is recommended in its entirety both for men and women (flexed arm-hang in lieu of pull-ups).

B. RECOMMENDATIONS

The following recommendations are made for further study:

1. A study should be undertaken with a proper experimental design to validate the effects of the proposal to shift the Marine Corps PFT to three profiles: aerobic, muscular, and body composition. To obtain a perspective on which aspects of fitness should carry the most weight, a cross validation should be conducted to compare scores with the obstacle course, endurance course, combat conditioning course, and/or the old physical readiness test to ensure proper values are assigned to each profile. Additionally, the classification scores and cutting scores should be investigated for any necessary adjustments.
2. Longitudinal studies should be made to measure changes in body composition variables in order to study the effect of age on physical performance. The percentile scores for respective body-fat percentages, presented in Appendix C, should be validated. Appropriate alternative cut-off scores should be investigated/determined to compensate for the effects of aging on performance and body composition.

APPENDIX A. BOX PLOTS OF PFT PERFORMANCE

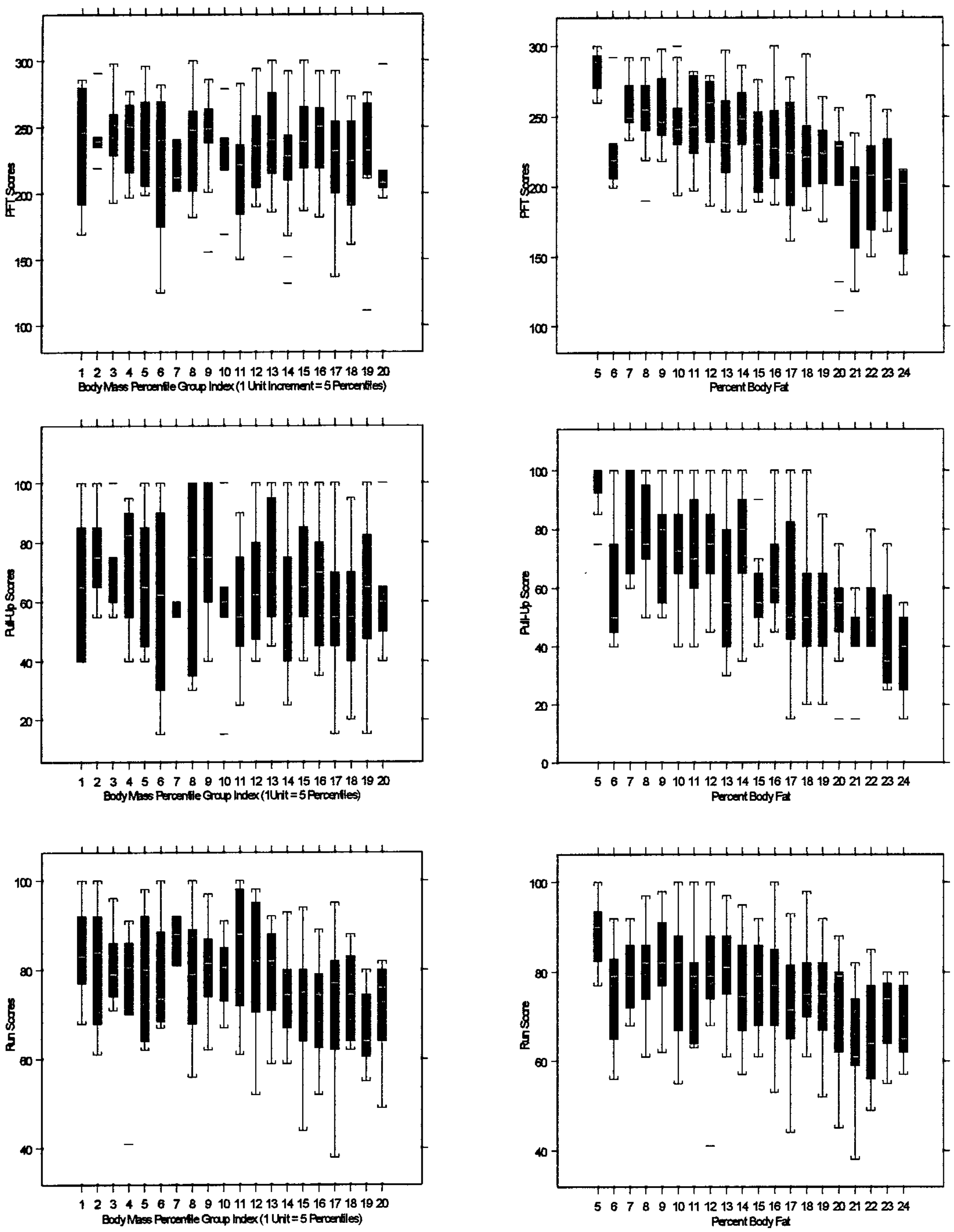


Figure A-1. Boxplots Comparing Trends in Mean PFT Scores Based on Percent Body Fat and Body Mass Percentile Groups.

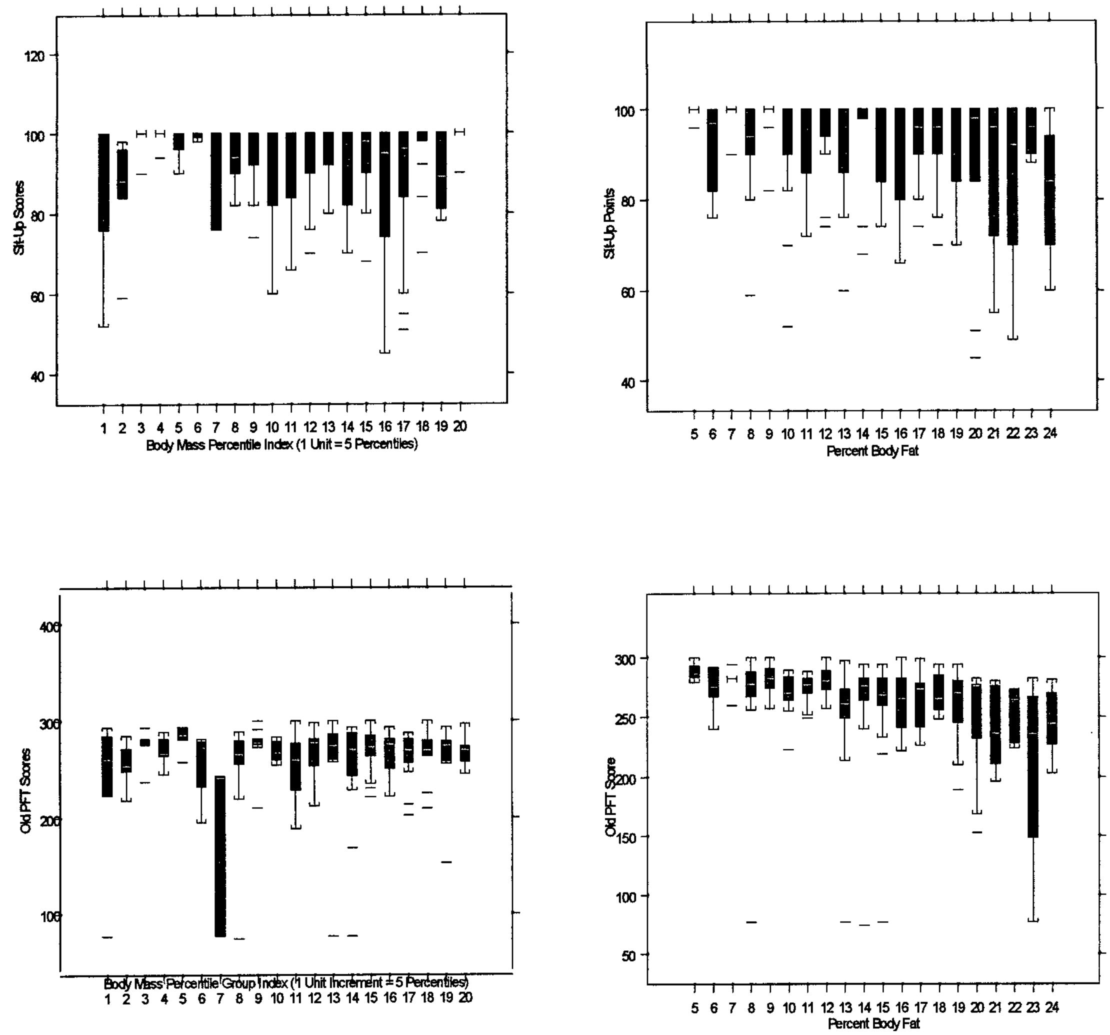


Figure A-2. Boxplots Comparing Trends in Mean PFT Scores Based on Percent Body Fat and Body Mass Percentile Groups (Continued).

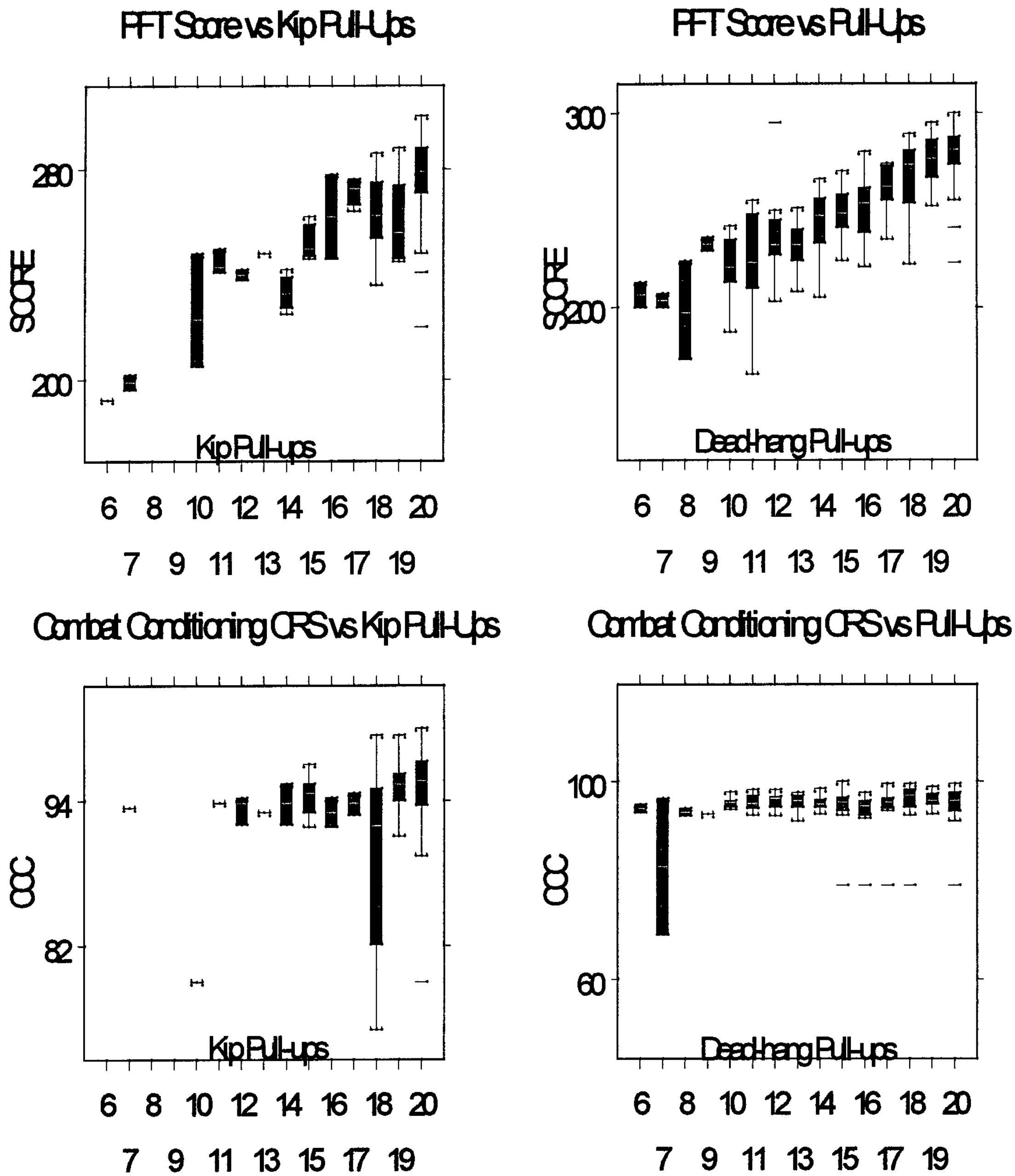


Figure A-3. Boxplots Comparing Trends in Mean Pull-Up Scores Based on other Events (Data Set 3).

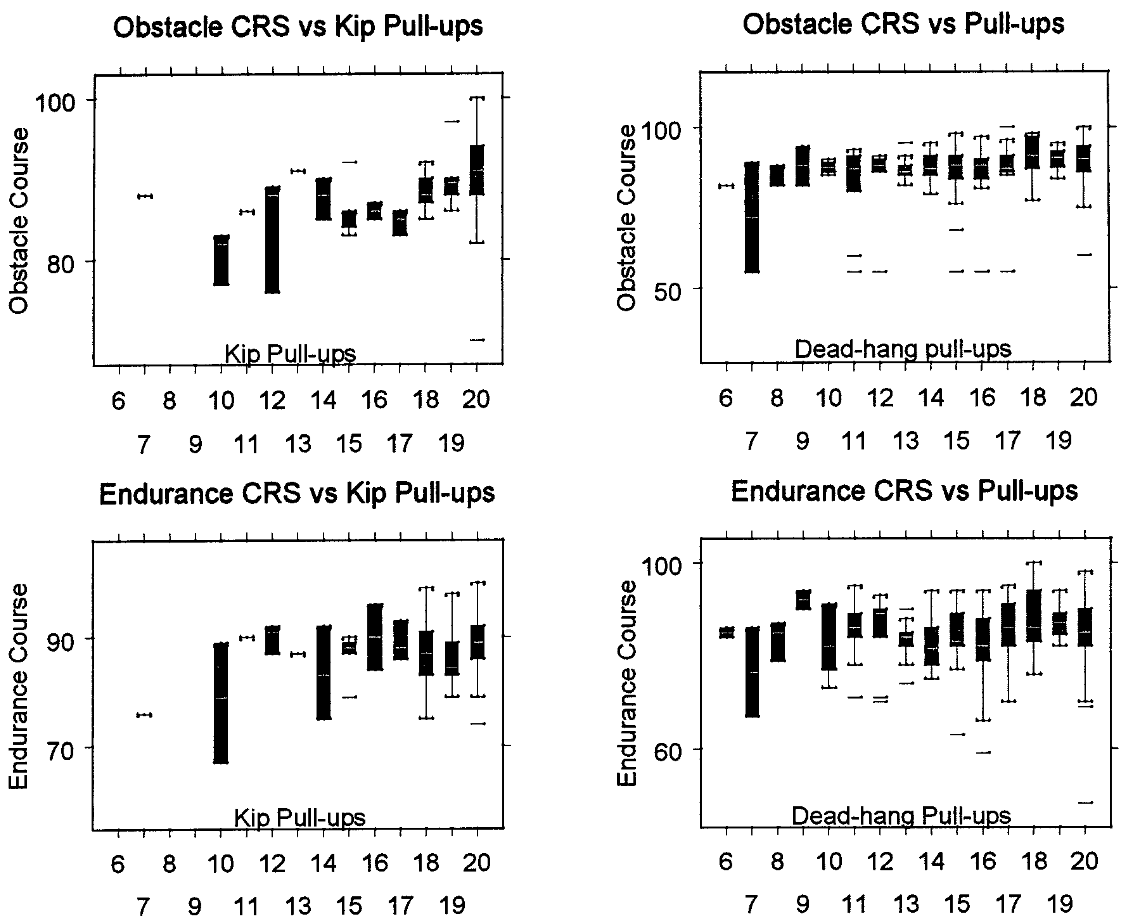


Figure 3. 2 Boxplots Comparing Trends in Mean Pull-Up Scores Based on other Events (Data Set 3).

APPENDIX B. PERCENT BODY-FAT TABLE

Height (in.) cross referenced with Difference Value (in.) = waist – neck

Diff. value	Height (inches)																			
	60	60.5	61	61.5	62	62.5	63	63.5	64	64.5	65	65.5	66	66.5	67	67.5	68	68.5	69	69.5
12.5	5	5	5	4	4	4	4	3	3	3	3	3	2	2	2	2	2	1	1	1
13	6	6	6	6	6	5	5	5	5	5	4	4	4	4	3	3	3	3	3	2
13.5	8	8	7	7	7	7	7	6	6	6	6	6	5	5	5	5	4	4	4	4
14	9	9	9	9	8	8	8	8	7	7	7	7	7	6	6	6	6	6	5	5
14.5	11	10	10	10	10	9	9	9	9	9	8	8	8	8	8	7	7	7	7	7
15	12	12	11	11	11	11	10	10	10	10	10	9	9	9	9	9	8	8	8	8
15.5	13	13	13	12	12	12	12	12	11	11	11	11	10	10	10	10	10	9	9	9
16	14	14	14	14	13	13	13	13	12	12	12	12	12	11	11	11	11	11	10	10
16.5	15	15	15	15	14	14	14	14	14	13	13	13	13	13	12	12	12	12	12	11
17	16	16	16	16	16	15	15	15	15	15	14	14	14	14	13	13	13	13	13	12
17.5	18	17	17	17	17	16	16	16	16	16	15	15	15	15	15	14	14	14	14	14
18	19	18	18	18	18	18	17	17	17	17	16	16	16	16	16	15	15	15	15	15
18.5	20	19	19	19	19	19	18	18	18	18	17	17	17	17	17	16	16	16	16	16
19	21	20	20	20	20	20	19	19	19	19	18	18	18	18	18	17	17	17	17	17
19.5	22	21	21	21	21	20	20	20	20	20	19	19	19	19	19	18	18	18	18	18
20	23	22	22	22	22	21	21	21	21	21	20	20	20	20	20	19	19	19	19	19
20.5	23	23	23	23	23	22	22	22	22	21	21	21	21	21	20	20	20	20	20	19
21	24	24	24	24	23	23	23	23	23	22	22	22	22	22	21	21	21	21	21	20
21.5	25	25	25	25	24	24	24	24	23	23	23	23	23	22	22	22	22	22	21	21
22	26	26	26	25	25	25	25	25	24	24	24	24	24	23	23	23	23	22	22	22
22.5	27	27	26	26	26	26	26	25	25	25	25	25	24	24	24	24	24	23	23	23
23	28	28	27	27	27	27	26	26	26	26	26	25	25	25	25	25	24	24	24	24
23.5	29	28	28	28	28	27	27	27	27	27	26	26	26	26	26	25	25	25	25	25
24	29	29	29	29	28	28	28	28	28	27	27	27	27	27	26	26	26	26	26	25
24.5	30	30	30	29	29	29	29	29	28	28	28	28	28	27	27	27	27	27	26	26
25	31	31	30	30	30	30	30	29	29	29	29	28	28	28	28	28	27	27	27	27
25.5	32	31	31	31	31	30	30	30	30	30	29	29	29	29	29	28	28	28	28	28
26	32	32	32	32	31	31	31	31	31	30	30	30	30	30	29	29	29	29	29	28
26.5	33	33	33	32	32	32	32	31	31	31	31	31	30	30	30	30	30	29	29	29
27	34	33	33	33	33	33	32	32	32	32	32	31	31	31	31	31	30	30	30	30
27.5	34	34	34	34	34	33	33	33	33	32	32	32	32	32	31	31	31	31	31	30
28	35	35	35	34	34	34	34	34	33	33	33	33	32	32	32	32	32	31	31	31
28.5	36	36	35	35	35	35	34	34	34	34	34	33	33	33	33	33	32	32	32	32
29	36	36	36	36	35	35	35	35	35	34	34	34	34	34	33	33	33	33	33	32
29.5	37	37	37	36	36	36	36	35	35	35	35	35	34	34	34	34	34	33	33	33
30	38	37	37	37	37	37	36	36	36	36	35	35	35	35	35	34	34	34	34	34

APPENDIX B. PERCENT BODY-FAT TABLE

Height (in.) cross referenced with Difference Value (in.) = waist – neck

Diff. value	Height (inches)																			
	70	70.5	71	71.5	72	72.5	73	73.5	74	74.5	75	75.5	76	76.5	77	77.5	78	78.5	79	79.5
12.5	1	1																		
13	2	2	2	2	2	1	1	1	1	1										
13.5	4	4	3	3	3	3	3	2	2	2	2	2	1	1	1	1	1	1		
14	5	5	5	4	4	4	4	4	4	3	3	3	3	3	2	2	2	2	2	2
14.5	6	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4	3	3	3	3
15	8	7	7	7	7	7	6	6	6	6	6	6	5	5	5	5	5	5	4	4
15.5	9	9	8	8	8	8	8	8	7	7	7	7	7	6	6	6	6	6	6	5
16	10	10	10	9	9	9	9	9	9	8	8	8	8	8	7	7	7	7	7	7
16.5	11	11	11	11	10	10	10	10	10	9	9	9	9	9	9	8	8	8	8	8
17	12	12	12	12	12	11	11	11	11	11	10	10	10	10	10	10	9	9	9	9
17.5	13	13	13	13	13	12	12	12	12	12	12	11	11	11	11	11	10	10	10	10
18	14	14	14	14	14	13	13	13	13	13	13	12	12	12	12	12	11	11	11	11
18.5	15	15	15	15	15	14	14	14	14	14	14	13	13	13	13	13	13	12	12	12
19	16	16	16	16	16	15	15	15	15	15	15	14	14	14	14	14	14	13	13	13
19.5	17	17	17	17	17	16	16	16	16	16	16	15	15	15	15	15	14	14	14	14
20	18	18	18	18	18	17	17	17	17	17	16	16	16	16	16	16	15	15	15	15
20.5	19	19	19	19	19	18	18	18	18	18	17	17	17	17	17	17	16	16	16	16
21	20	20	20	20	19	19	19	19	19	18	18	18	18	18	18	17	17	17	17	17
21.5	21	21	21	20	20	20	20	20	20	19	19	19	19	19	18	18	18	18	18	18
22	22	22	22	21	21	21	21	21	20	20	20	20	20	19	19	19	19	19	19	18
22.5	23	23	22	22	22	22	22	21	21	21	21	21	21	20	20	20	20	20	19	19
23	24	23	23	23	23	23	22	22	22	22	22	22	21	21	21	21	21	20	20	20
23.5	24	24	24	24	24	23	23	23	23	23	22	22	22	22	22	22	21	21	21	21
24	25	25	25	25	24	24	24	24	24	23	23	23	23	23	23	22	22	22	22	22
24.5	26	26	26	25	25	25	25	25	24	24	24	24	24	24	23	23	23	23	23	22
25	27	26	26	26	26	26	26	25	25	25	25	25	24	24	24	24	24	24	23	23
25.5	27	27	27	27	27	26	26	26	26	26	26	25	25	25	25	25	24	24	24	24
26	28	28	28	28	27	27	27	27	27	26	26	26	26	26	26	25	25	25	25	25
26.5	29	29	28	28	28	28	28	28	27	27	27	27	27	26	26	26	26	26	26	25
27	30	29	29	29	29	29	28	28	28	28	28	27	27	27	27	27	27	26	26	26
27.5	30	30	30	30	29	29	29	29	29	29	28	28	28	28	28	27	27	27	27	27
28	31	13	31	30	30	30	30	30	29	29	29	29	29	28	28	28	28	28	28	27
28.5	32	31	31	31	31	31	30	30	30	30	30	29	29	29	29	29	29	28	28	28
29	32	32	32	32	31	31	31	31	31	31	30	30	30	30	30	29	29	29	29	29
29.5	33	33	32	32	32	32	32	32	31	31	31	31	31	30	30	30	30	30	30	29
30	33	33	33	33	33	33	32	32	32	32	32	31	31	31	31	31	31	30	30	30

APPENDIX C. SCORES FOR BODY-FAT PERCENTAGE

Males (age)					Percentile	Females (age)				
17-19	20-29	30-39	40-49	50+	Score	17-19	20-29	30-39	40-49	50+
7.6	9.9	10.5	11.0	13.7	100	9.8	10.0	9.2	10.2	11.2
8.8	11.1	15.2	16.9	19.2	95	15.1	15.3	15.0	16.1	17.2
10.3	12.6	16.1	18.1	20.3	90	16.2	16.3	16.1	17.2	18.2
11.2	13.5	17.3	19.5	21.7	85	17.5	17.6	17.6	18.7	19.2
12.0	14.2	18.0	20.4	22.5	80	18.3	18.3	18.4	19.5	20.2
12.7	14.9	18.6	21.2	23.2	75	18.9	19.0	19.1	20.3	21.2
13.3	15.4	19.2	21.8	23.8	70	19.5	19.5	19.8	20.9	22.1
13.9	16.1	19.6	22.4	24.3	65	20.0	20.0	20.4	21.5	22.6
14.5	16.6	20.1	23.0	24.9	60	20.6	20.6	21.0	22.1	23.2
15.1	17.2	20.5	23.5	25.4	55	21.1	21.0	21.5	22.6	24.1
15.7	17.7	21.0	24.1	25.9	50	21.6	21.5	22.0	23.2	24.6
16.2	18.3	21.5	24.7	26.4	45	22.1	22.0	22.6	23.7	25.1
16.9	18.9	21.9	25.2	26.9	40	22.5	22.5	23.1	24.3	25.6
17.5	19.5	22.4	25.8	27.5	35	23.1	23.0	23.7	24.9	26.2
18.2	20.1	22.8	26.3	28.0	30	23.6	23.5	24.3	25.4	27.2
18.9	20.9	23.4	27.0	28.7	25	24.2	24.1	24.9	26.1	27.7
19.8	21.8	24.0	27.8	29.3	20	24.9	24.7	25.6	26.8	28.2
21.4	23.3	24.7	28.6	30.2	15	25.6	25.5	26.5	27.7	29.2
22.6	24.4	25.9	30.1	31.6	10	27.0	26.8	27.9	29.1	30.2
23.2	25.9	26.8	31.2	32.6	5	28.0	27.8	29.1	30.3	32.2
27.1	32.9	34.2	37.2	38.2	0	33.3	32.9	34.9	36.2	38.2

APPENDIX D. TOTAL WORK DONE WITH PULL-UPS SCORING OPTION

Appendix D-1 Work Done (ft.lbs.) per Pull-up Based on Height and Weight

Weight (lbs.)	Height (inches)																
	64	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**
105	112	114	116	117	119	121	123	124	126	128	130	131	133	135	137	138	140
106	113	115	117	118	120	122	124	125	127	129	131	133	134	136	138	140	141
107	114	116	118	119	121	123	125	127	128	130	132	134	136	137	139	141	143
108	115	117	119	121	122	124	126	128	130	131	133	135	137	139	140	142	144
109	116	118	120	122	124	125	127	129	131	133	134	136	138	140	142	144	145
110	117	119	121	123	125	127	128	130	132	134	136	138	139	141	143	145	147
111	118	120	122	124	126	128	130	131	133	135	137	139	141	142	144	146	148
112	119	121	123	125	127	129	131	133	134	136	138	140	142	144	146	147	149
113	121	122	124	126	128	130	132	134	136	137	139	141	143	145	147	149	151
114	122	124	125	127	129	131	133	135	137	139	141	143	144	146	148	150	152
115	123	125	127	128	130	132	134	136	138	140	142	144	146	148	150	151	153
116	124	126	128	130	131	133	135	137	139	141	143	145	147	149	151	153	155
117	125	127	129	131	133	135	137	138	140	142	144	146	148	150	152	154	156
118	126	128	130	132	134	136	138	140	142	144	146	148	149	151	153	155	157
119	127	129	131	133	135	137	139	141	143	145	147	149	151	153	155	157	159
120	128	130	132	134	136	138	140	142	144	146	148	150	152	154	156	158	160
121	129	131	133	135	137	139	141	143	145	147	149	151	153	155	157	159	161
122	130	132	134	136	138	140	142	144	146	148	150	153	155	157	159	161	163
123	131	133	135	137	139	141	144	146	148	150	152	154	156	158	160	162	164
124	132	134	136	138	141	143	145	147	149	151	153	155	157	159	161	163	165
125	133	135	138	140	142	144	146	148	150	152	154	156	158	160	163	165	167
126	134	137	139	141	143	145	147	149	151	153	155	158	160	162	164	166	168
127	135	138	140	142	144	146	148	150	152	155	157	159	161	163	165	167	169
128	137	139	141	143	145	147	149	151	154	156	158	160	162	164	166	169	171
129	138	140	142	144	146	148	151	153	155	157	159	161	163	166	168	170	172
130	139	141	143	145	147	150	152	154	156	158	160	163	165	167	169	171	173
131	140	142	144	146	148	151	153	155	157	159	162	164	166	168	170	172	175
132	141	143	145	147	150	152	154	156	158	161	163	165	167	169	172	174	176
133	142	144	146	149	151	153	155	157	160	162	164	166	168	171	173	175	177
134	143	145	147	150	152	154	156	159	161	163	165	168	170	172	174	176	179
135	144	146	149	151	153	155	158	160	162	164	167	169	171	173	176	178	180
136	145	147	150	152	154	156	159	161	163	165	168	170	172	175	177	179	181
137	146	148	151	153	155	158	160	162	164	167	169	171	174	176	178	180	183
138	147	150	152	154	156	159	161	163	166	168	170	173	175	177	179	182	184
139	148	151	153	155	158	160	162	164	167	169	171	174	176	178	181	183	185
140	149	152	154	156	159	161	163	166	168	170	173	175	177	180	182	184	187
141	150	153	155	157	160	162	165	167	169	172	174	176	179	181	183	186	188
142	151	154	156	159	161	163	166	168	170	173	175	178	180	182	185	187	189
143	153	155	157	160	162	164	167	169	172	174	176	179	181	184	186	188	191
144	154	156	158	161	163	166	168	170	173	175	178	180	182	185	187	190	192
145	155	157	160	162	164	167	169	172	174	176	179	181	184	186	189	191	193
146	156	158	161	163	165	168	170	173	175	178	180	183	185	187	190	192	195
147	157	159	162	164	167	169	172	174	176	179	181	184	186	189	191	194	196

Weight (lbs.)	Height (inches)																
	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
1[illegible]	158	160	163	165	168	170	173	175	178	180	183	185	187	190	192	195	197
14[illegible]	159	161	164	166	169	171	174	176	179	181	184	186	189	191	194	196	199
15[illegible]	160	163	165	168	170	173	175	178	180	183	185	188	190	193	195	198	200
151	161	164	166	169	171	174	176	179	181	184	186	189	191	194	196	199	201
152	162	165	167	170	172	175	177	180	182	185	187	190	193	195	198	200	203
153	163	166	168	171	173	176	179	181	184	186	189	191	194	196	199	201	204
154	164	167	169	172	175	177	180	182	185	187	190	193	195	198	200	203	205
155	165	168	171	173	176	178	181	183	186	189	191	194	196	199	202	204	207
156	166	169	172	174	177	179	182	185	187	190	192	195	198	200	203	205	208
157	167	170	173	175	178	181	183	186	188	191	194	196	199	201	204	207	209
158	169	171	174	176	179	182	184	187	190	192	195	198	200	203	205	208	211
159	170	172	175	178	180	183	186	188	191	193	196	199	201	204	207	209	212
160	171	173	176	179	181	184	187	189	192	195	197	200	203	205	208	211	213
161	172	174	177	180	182	185	188	191	193	196	199	201	204	207	209	212	215
162	173	176	178	181	184	186	189	192	194	197	200	203	205	208	211	213	216
163	174	177	179	182	185	187	190	193	196	198	201	204	206	209	212	215	217
164	175	178	180	183	186	189	191	194	197	200	202	205	208	210	213	216	219
165	176	179	182	184	187	190	193	195	198	201	204	206	209	212	215	217	220
166	177	180	183	185	188	191	194	196	199	202	205	208	210	213	216	219	221
167	178	181	184	186	189	192	195	198	200	203	206	209	212	214	217	220	223
168	179	182	185	188	190	193	196	199	202	204	207	210	213	216	218	221	224
169	180	183	186	189	192	194	197	200	203	206	208	211	214	217	220	223	225
170	181	184	187	190	193	196	198	201	204	207	210	213	215	218	221	224	227
171	182	185	188	191	194	197	200	202	205	208	211	214	217	219	222	225	228
172	183	186	189	192	195	198	201	204	206	209	212	215	218	221	224	226	229
173	185	187	190	193	196	199	202	205	208	210	213	216	219	222	225	228	231
174	186	189	191	194	197	200	203	206	209	212	215	218	220	223	226	229	232
175	187	190	193	195	198	201	204	207	210	213	216	219	222	225	228	230	233
176	188	191	194	197	199	202	205	208	211	214	217	220	223	226	229	232	235
177	189	192	195	198	201	204	207	209	212	215	218	221	224	227	230	233	236
178	190	193	196	199	202	205	208	211	214	217	220	223	225	228	231	234	237
179	191	194	197	200	203	206	209	212	215	218	221	224	227	230	233	236	239
180	192	195	198	201	204	207	210	213	216	219	222	225	228	231	234	237	240
181	193	196	199	202	205	208	211	214	217	220	223	226	229	232	235	238	241
182	194	197	200	203	206	209	212	215	218	221	224	228	231	234	237	240	243
183	195	198	201	204	207	210	214	217	220	223	226	229	232	235	238	241	244
184	196	199	202	205	209	212	215	218	221	224	227	230	233	236	239	242	245
185	197	200	204	207	210	213	216	219	222	225	228	231	234	237	241	244	247
186	198	202	205	208	211	214	217	220	223	226	229	233	236	239	242	245	248
187	199	203	206	209	212	215	218	221	224	228	231	234	237	240	243	246	249
188	201	204	207	210	213	216	219	222	226	229	232	235	238	241	244	248	251
189	202	205	208	211	214	217	221	224	227	230	233	236	239	243	246	249	252
190	203	206	209	212	215	219	222	225	228	231	234	238	241	244	247	250	253
191	204	207	210	213	216	220	223	226	229	232	236	239	242	245	248	251	255
192	205	208	211	214	218	221	224	227	230	234	237	240	243	246	250	253	256
193	206	209	212	216	219	222	225	228	232	235	238	241	244	248	251	254	257

Weight (lbs.)	Height (inches)																
	64	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**
194	207	210	213	217	220	223	226	230	233	236	239	243	246	249	252	255	259
195	208	211	215	218	221	224	228	231	234	237	241	244	247	250	254	257	260
196	209	212	216	219	222	225	229	232	235	238	242	245	248	252	255	258	261
197	210	213	217	220	223	227	230	233	236	240	243	246	250	253	256	259	263
198	211	215	218	221	224	228	231	234	238	241	244	248	251	254	257	261	264
199	212	216	219	222	226	229	232	235	239	242	245	249	252	255	259	262	265
200	213	217	220	223	227	230	233	237	240	243	247	250	253	257	260	263	267
201	214	218	221	224	228	231	235	238	241	245	248	251	255	258	261	265	268
202	215	219	222	226	229	232	236	239	242	246	249	253	256	259	263	266	269
203	217	220	223	227	230	233	237	240	244	247	250	254	257	261	264	267	271
204	218	221	224	228	231	235	238	241	245	248	252	255	258	262	265	269	272
205	219	222	226	229	232	236	239	243	246	249	253	256	260	263	267	270	273
206	220	223	227	230	233	237	240	244	247	251	254	258	261	264	268	271	275
207	221	224	228	231	235	238	242	245	248	252	255	259	262	266	269	273	276
208	222	225	229	232	236	239	243	246	250	253	257	260	263	267	270	274	277
209	223	226	230	233	237	240	244	247	251	254	258	261	265	268	272	275	279
210	224	228	231	235	238	242	245	249	252	256	259	263	266	270	273	277	280
211	225	229	232	236	239	243	246	250	253	257	260	264	267	271	274	278	281
212	226	230	233	237	240	244	247	251	254	258	261	265	269	272	276	279	283
213	227	231	234	238	241	245	249	252	256	259	263	266	270	273	277	280	284
214	228	232	235	239	243	246	250	253	257	260	264	268	271	275	278	282	285
215	229	233	237	240	244	247	251	254	258	262	265	269	272	276	280	283	287
216	230	234	238	241	245	248	252	256	259	263	266	270	274	277	281	284	288
217	231	235	239	242	246	250	253	257	260	264	268	271	275	278	282	286	289
218	233	236	240	243	247	251	254	258	262	265	269	273	276	280	283	287	291
219	234	237	241	245	248	252	256	259	263	266	270	274	277	281	285	288	292
220	235	238	242	246	249	253	257	260	264	268	271	275	279	282	286	290	293
221	236	239	243	247	250	254	258	262	265	269	273	276	280	284	287	291	295
222	237	241	244	248	252	255	259	263	266	270	274	278	281	285	289	292	296
223	238	242	245	249	253	256	260	264	268	271	275	279	282	286	290	294	297
224	239	243	246	250	254	258	261	265	269	273	276	280	284	287	291	295	299
225	240	244	248	251	255	259	263	266	270	274	278	281	285	289	293	296	300
226	241	245	249	252	256	260	264	267	271	275	279	283	286	290	294	298	301
227	242	246	250	253	257	261	265	269	272	276	280	284	288	291	295	299	303
228	243	247	251	255	258	262	266	270	274	277	281	285	289	293	296	300	304
229	244	248	252	256	260	263	267	271	275	279	282	286	290	294	298	302	305
230	245	249	253	257	261	265	268	272	276	280	284	288	291	295	299	303	307
231	246	250	254	258	262	266	270	273	277	281	285	289	293	296	300	304	308
232	247	251	255	259	263	267	271	275	278	282	286	290	294	298	302	305	309
233	249	252	256	260	264	268	272	276	280	283	287	291	295	299	303	307	311
234	250	254	257	261	265	269	273	277	281	285	289	293	296	300	304	308	312
235	251	255	259	262	266	270	274	278	282	286	290	294	298	302	306	309	313
236	252	256	260	264	267	271	275	279	283	287	291	295	299	303	307	311	315
237	253	257	261	265	269	273	277	280	284	288	292	296	300	304	308	312	316
238	254	258	262	266	270	274	278	282	286	290	294	298	301	305	309	313	317
239	255	259	263	267	271	275	279	283	287	291	295	299	303	307	311	315	319

Weight (lbs.)	Height (inches)																
	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
240	256	260	264	268	272	276	280	284	288	292	296	300	304	308	312	316	320
241	257	261	265	269	273	277	281	285	289	293	297	301	305	309	313	317	321
242	258	262	266	270	274	278	282	286	290	294	298	303	307	311	315	319	323
243	259	263	267	271	275	279	284	288	292	296	300	304	308	312	316	320	324
244	260	264	268	272	277	281	285	289	293	297	301	305	309	313	317	321	325
245	261	265	270	274	278	282	286	290	294	298	302	306	310	314	319	323	327
246	262	267	271	275	279	283	287	291	295	299	303	308	312	316	320	324	328
247	263	268	272	276	280	284	288	292	296	301	305	309	313	317	321	325	329
248	265	269	273	277	281	285	289	293	298	302	306	310	314	318	322	327	331
249	266	270	274	278	282	286	291	295	299	303	307	311	315	320	324	328	332
250	267	271	275	279	283	288	292	296	300	304	308	313	317	321	325	329	333

Appendix D-2. Total Work Done with Total Number of Pull-ups Executed

Work /P.U.	Number of Pull-ups executed																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
112	112	224	336	448	560	672	784	896	1008	1120	1232	1344	1456	1568	1680	1792	1904	2016	2128	2240
113	113	226	339	452	565	678	791	904	1017	1130	1243	1356	1469	1582	1695	1808	1921	2034	2147	2260
114	114	228	342	456	570	684	798	912	1026	1140	1254	1368	1482	1596	1710	1824	1938	2052	2166	2280
115	115	230	345	460	575	690	805	920	1035	1150	1265	1380	1495	1610	1725	1840	1955	2070	2185	2300
116	116	232	348	464	580	696	812	928	1044	1160	1276	1392	1508	1624	1740	1856	1972	2088	2204	2320
117	117	234	351	468	585	702	819	936	1053	1170	1287	1404	1521	1638	1755	1872	1989	2106	2223	2340
118	118	236	354	472	590	708	826	944	1062	1180	1298	1416	1534	1652	1770	1888	2006	2124	2242	2360
119	119	238	357	476	595	714	833	952	1071	1190	1309	1428	1547	1666	1785	1904	2023	2142	2261	2380
120	120	240	360	480	600	720	840	960	1080	1200	1320	1440	1560	1680	1800	1920	2040	2160	2280	2400
121	121	242	363	484	605	726	847	968	1089	1210	1331	1452	1573	1694	1815	1936	2057	2178	2299	2420
122	122	244	366	488	610	732	854	976	1098	1220	1342	1464	1586	1708	1830	1952	2074	2196	2318	2440
123	123	246	369	492	615	738	861	984	1107	1230	1353	1476	1599	1722	1845	1968	2091	2214	2337	2460
124	124	248	372	496	620	744	868	992	1116	1240	1364	1488	1612	1736	1860	1984	2108	2232	2356	2480
125	125	250	375	500	625	750	875	1000	1125	1250	1375	1500	1625	1750	1875	2000	2125	2250	2375	2500
126	126	252	378	504	630	756	882	1008	1134	1260	1386	1512	1638	1764	1890	2016	2142	2268	2394	2520
127	127	254	381	508	635	762	889	1016	1143	1270	1397	1524	1651	1778	1905	2032	2159	2286	2413	2540
128	128	256	384	512	640	768	896	1024	1152	1280	1408	1536	1664	1792	1920	2048	2176	2304	2432	2560
129	129	258	387	516	645	774	903	1032	1161	1290	1419	1548	1677	1806	1935	2064	2193	2322	2451	2580
130	130	260	390	520	650	780	910	1040	1170	1300	1430	1560	1690	1820	1950	2080	2210	2340	2470	2600
131	131	262	393	524	655	786	917	1048	1179	1310	1441	1572	1703	1834	1965	2096	2227	2358	2489	2620
132	132	264	396	528	660	792	924	1056	1188	1320	1452	1584	1716	1848	1980	2112	2244	2376	2508	2640
133	133	266	399	532	665	798	931	1064	1197	1330	1463	1596	1729	1862	1995	2128	2261	2394	2527	2660
134	134	268	402	536	670	804	938	1072	1206	1340	1474	1608	1742	1876	2010	2144	2278	2412	2546	2680
135	135	270	405	540	675	810	945	1080	1215	1350	1485	1620	1755	1890	2025	2160	2295	2430	2565	2700
136	136	272	408	544	680	816	952	1088	1224	1360	1496	1632	1768	1904	2040	2176	2312	2448	2584	2720
137	137	274	411	548	685	822	959	1096	1233	1370	1507	1644	1781	1918	2055	2192	2329	2466	2603	2740
138	138	276	414	552	690	828	966	1104	1242	1380	1518	1656	1794	1932	2070	2208	2346	2484	2622	2760
139	139	278	417	556	695	834	973	1112	1251	1390	1529	1668	1807	1946	2085	2224	2363	2502	2641	2780
140	140	280	420	560	700	840	980	1120	1260	1400	1540	1680	1820	1960	2100	2240	2380	2520	2660	2800
141	141	282	423	564	705	846	987	1128	1269	1410	1551	1692	1833	1974	2115	2256	2397	2538	2679	2820

Work /P.U.	Number of Pull-ups executed																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
142	142	284	426	568	710	852	994	1136	1278	1420	1562	1704	1846	1988	2130	2272	2414	2556	2698	2840
143	143	286	429	572	715	858	1001	1144	1287	1430	1573	1716	1859	2002	2145	2288	2431	2574	2717	2860
144	144	288	432	576	720	864	1008	1152	1296	1440	1584	1728	1872	2016	2160	2304	2448	2592	2736	2880
145	145	290	435	580	725	870	1015	1160	1305	1450	1595	1740	1885	2030	2175	2320	2465	2610	2755	2900
146	146	292	438	584	730	876	1022	1168	1314	1460	1606	1752	1898	2044	2190	2336	2482	2628	2774	2920
147	147	294	441	588	735	882	1029	1176	1323	1470	1617	1764	1911	2058	2205	2352	2499	2646	2793	2940
148	148	296	444	592	740	888	1036	1184	1332	1480	1628	1776	1924	2072	2220	2368	2516	2664	2812	2960
149	149	298	447	596	745	894	1043	1192	1341	1490	1639	1788	1937	2086	2235	2384	2533	2682	2831	2980
150	150	300	450	600	750	900	1050	1200	1350	1500	1650	1800	1950	2100	2250	2400	2550	2700	2850	3000
151	151	302	453	604	755	906	1057	1208	1359	1510	1661	1812	1963	2114	2265	2416	2567	2718	2869	3020
152	152	304	456	608	760	912	1064	1216	1368	1520	1672	1824	1976	2128	2280	2432	2584	2736	2888	3040
153	153	306	459	612	765	918	1071	1224	1377	1530	1683	1836	1989	2142	2295	2448	2601	2754	2907	3060
154	154	308	462	616	770	924	1078	1232	1386	1540	1694	1848	2002	2156	2310	2464	2618	2772	2926	3080
155	155	310	465	620	775	930	1085	1240	1395	1550	1705	1860	2015	2170	2325	2480	2635	2790	2945	3100
156	156	312	468	624	780	936	1092	1248	1404	1560	1716	1872	2028	2184	2340	2496	2652	2808	2964	3120
157	157	314	471	628	785	942	1099	1256	1413	1570	1727	1884	2041	2198	2355	2512	2669	2826	2983	3140
158	158	316	474	632	790	948	1106	1264	1422	1580	1738	1896	2054	2212	2370	2528	2686	2844	3002	3160
159	159	318	477	636	795	954	1113	1272	1431	1590	1749	1908	2067	2226	2385	2544	2703	2862	3021	3180
160	160	320	480	640	800	960	1120	1280	1440	1600	1760	1920	2080	2240	2400	2560	2720	2880	3040	3200
161	161	322	483	644	805	966	1127	1288	1449	1610	1771	1932	2093	2254	2415	2576	2737	2898	3059	3220
162	162	324	486	648	810	972	1134	1296	1458	1620	1782	1944	2106	2268	2430	2592	2754	2916	3078	3240
163	163	326	489	652	815	978	1141	1304	1467	1630	1793	1956	2119	2282	2445	2608	2771	2934	3097	3260
164	164	328	492	656	820	984	1148	1312	1476	1640	1804	1968	2132	2296	2460	2624	2788	2952	3116	3280
165	165	330	495	660	825	990	1155	1320	1485	1650	1815	1980	2145	2310	2475	2640	2805	2970	3135	3300
166	166	332	498	664	830	996	1162	1328	1494	1660	1826	1992	2158	2324	2490	2656	2822	2988	3154	3320
167	167	334	501	668	835	1002	1169	1336	1503	1670	1837	2004	2171	2338	2505	2672	2839	3006	3173	3340
168	168	336	504	672	840	1008	1176	1344	1512	1680	1848	2016	2184	2352	2520	2688	2856	3024	3192	3360
169	169	338	507	676	845	1014	1183	1352	1521	1690	1859	2028	2197	2366	2535	2704	2873	3042	3211	3380
170	170	340	510	680	850	1020	1190	1360	1530	1700	1870	2040	2210	2380	2550	2720	2890	3060	3230	3400
171	171	342	513	684	855	1026	1197	1368	1539	1710	1881	2052	2223	2394	2565	2736	2907	3078	3249	3420
172	172	344	516	688	860	1032	1204	1376	1548	1720	1892	2064	2236	2408	2580	2752	2924	3096	3268	3440
173	173	346	519	692	865	1038	1211	1384	1557	1730	1903	2076	2249	2422	2595	2768	2941	3114	3287	3460
174	174	348	522	696	870	1044	1218	1392	1566	1740	1914	2088	2262	2436	2610	2784	2958	3132	3306	3480
175	175	350	525	700	875	1050	1225	1400	1575	1750	1925	2100	2275	2450	2625	2800	2975	3150	3325	3500
176	176	352	528	704	880	1056	1232	1408	1584	1760	1936	2112	2288	2464	2640	2816	2992	3168	3344	3520
177	177	354	531	708	885	1062	1239	1416	1593	1770	1947	2124	2301	2478	2655	2832	3009	3186	3363	3540
178	178	356	534	712	890	1068	1246	1424	1602	1780	1958	2136	2314	2492	2670	2848	3026	3204	3382	3560
179	179	358	537	716	895	1074	1253	1432	1611	1790	1969	2148	2327	2506	2685	2864	3043	3222	3401	3580
180	180	360	540	720	900	1080	1260	1440	1620	1800	1980	2160	2340	2520	2700	2880	3060	3240	3420	3600
181	181	362	543	724	905	1086	1267	1448	1629	1810	1991	2172	2353	2534	2715	2896	3077	3258	3439	3620
182	182	364	546	728	910	1092	1274	1456	1638	1820	2002	2184	2366	2548	2730	2912	3094	3276	3458	3640
183	183	366	549	732	915	1098	1281	1464	1647	1830	2013	2196	2379	2562	2745	2928	3111	3294	3477	3660
184	184	368	552	736	920	1104	1288	1472	1656	1840	2024	2208	2392	2576	2760	2944	3128	3312	3496	3680
185	185	370	555	740	925	1110	1295	1480	1665	1850	2035	2220	2405	2590	2775	2960	3145	3330	3515	3700
186	186	372	558	744	930	1116	1302	1488	1674	1860	2046	2232	2418	2604	2790	2976	3162	3348	3534	3720
187	187	374	561	748	935	1122	1309	1496	1683	1870	2057	2244	2431	2618	2805	2992	3179	3366	3553	3740

Work /P.U.	Number of Pull-ups executed																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
188	188	376	564	752	940	1128	1316	1504	1692	1880	2068	2256	2444	2632	2820	3008	3196	3384	3572	3760
189	189	378	567	756	945	1134	1323	1512	1701	1890	2079	2268	2457	2646	2835	3024	3213	3402	3591	3780
190	190	380	570	760	950	1140	1330	1520	1710	1900	2090	2280	2470	2660	2850	3040	3230	3420	3610	3800
191	191	382	573	764	955	1146	1337	1528	1719	1910	2101	2292	2483	2674	2865	3056	3247	3438	3629	3820
192	192	384	576	768	960	1152	1344	1536	1728	1920	2112	2304	2496	2688	2880	3072	3264	3456	3648	3840
193	193	386	579	772	965	1158	1351	1544	1737	1930	2123	2316	2509	2702	2895	3088	3281	3474	3667	3860
194	194	388	582	776	970	1164	1358	1552	1746	1940	2134	2328	2522	2716	2910	3104	3298	3492	3686	3880
195	195	390	585	780	975	1170	1365	1560	1755	1950	2145	2340	2535	2730	2925	3120	3315	3510	3705	3900
196	196	392	588	784	980	1176	1372	1568	1764	1960	2156	2352	2548	2744	2940	3136	3332	3528	3724	3920
197	197	394	591	788	985	1182	1379	1576	1773	1970	2167	2364	2561	2758	2955	3152	3349	3546	3743	3940
198	198	396	594	792	990	1188	1386	1584	1782	1980	2178	2376	2574	2772	2970	3168	3366	3564	3762	3960
199	199	398	597	796	995	1194	1393	1592	1791	1990	2189	2388	2587	2786	2985	3184	3383	3582	3781	3980
200	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
201	201	402	603	804	1005	1206	1407	1608	1809	2010	2211	2412	2613	2814	3015	3216	3417	3618	3819	4020
202	202	404	606	808	1010	1212	1414	1616	1818	2020	2222	2424	2626	2828	3030	3232	3434	3636	3838	4040
203	203	406	609	812	1015	1218	1421	1624	1827	2030	2233	2436	2639	2842	3045	3248	3451	3654	3857	4060
204	204	408	612	816	1020	1224	1428	1632	1836	2040	2244	2448	2652	2856	3060	3264	3468	3672	3876	4080
205	205	410	615	820	1025	1230	1435	1640	1845	2050	2255	2460	2665	2870	3075	3280	3485	3690	3895	4100
206	206	412	618	824	1030	1236	1442	1648	1854	2060	2266	2472	2678	2884	3090	3296	3502	3708	3914	4120
207	207	414	621	828	1035	1242	1449	1656	1863	2070	2277	2484	2691	2898	3105	3312	3519	3726	3933	4140
208	208	416	624	832	1040	1248	1456	1664	1872	2080	2288	2496	2704	2912	3120	3328	3536	3744	3952	4160
209	209	418	627	836	1045	1254	1463	1672	1881	2090	2299	2508	2717	2926	3135	3344	3553	3762	3971	4180
210	210	420	630	840	1050	1260	1470	1680	1890	2100	2310	2520	2730	2940	3150	3360	3570	3780	3990	4200
211	211	422	633	844	1055	1266	1477	1688	1899	2110	2321	2532	2743	[illegible]	3165	3376	3587	3798	4009	4220
212	212	424	636	848	1060	1272	1484	1696	1908	2120	2332	2544	2756	2968	3180	3392	3604	3816	4028	4240
213	213	426	639	852	1065	1278	1491	1704	1917	2130	2343	2556	2769	2982	3195	3408	3621	3834	4047	4260
214	214	428	642	856	1070	1284	1498	1712	1926	2140	2354	2568	2782	2996	3210	3424	3638	3852	4066	4280
215	215	430	645	860	1075	1290	1505	1720	1935	2150	2365	2580	2795	3010	3225	3440	3655	3870	4085	4300
216	216	432	648	864	1080	1296	1512	1728	1944	2160	2376	2592	2808	3024	3240	3456	3672	3888	4104	4320
217	217	434	651	868	1085	1302	1519	1736	1953	2170	2387	2604	2821	3038	3255	3472	3689	3906	4123	4340
218	218	436	654	872	1090	1308	1526	1744	1962	2180	2398	2616	2834	3052	3270	3488	3706	3924	4142	4360
219	219	438	657	876	1095	1314	1533	1752	1971	2190	2409	2628	2847	3066	3285	3504	3723	3942	4161	4380
220	220	440	660	880	1100	1320	1540	1760	1980	2200	2420	2640	2860	3080	3300	3520	3740	3960	4180	4400
221	221	442	663	884	1105	1326	1547	1768	1989	2210	2431	2652	2873	3094	3315	3536	3757	3978	4199	4420
222	222	444	666	888	1110	1332	1554	1776	1998	2220	2442	2664	2886	3108	3330	3552	3774	3996	4218	4440
223	223	446	669	892	1115	1338	1561	1784	2007	2230	2453	2676	2899	3122	3345	3568	3791	4014	4237	4460
224	224	448	[illegible]	896	1120	1344	1568	1792	2016	2240	2464	2688	2912	3136	3360	3584	3808	4032	4256	4480
225	225	450	675	900	1125	1350	1575	1800	2025	2250	2475	2700	2925	3150	3375	3600	3825	4050	4275	4500
226	226	452	678	904	1130	1356	1582	1808	2034	2260	2486	2712	2938	3164	3390	3616	3842	4068	4294	4520
227	227	454	681	908	1135	1362	1589	1816	2043	2270	2497	2724	2951	3178	3405	3632	3859	4086	4313	4540
228	228	456	684	912	1140	1368	1596	1824	2052	2280	2508	2736	2964	3192	3420	3648	3876	4104	4332	4560
229	229	458	687	916	1145	1374	1603	1832	2061	2290	2519	2748	2977	3206	3435	3664	3893	4122	4351	4580
230	230	460	690	920	1150	1380	1610	1840	2070	2300	2530	2760	2990	3220	3450	3680	3910	4140	4370	4600
231	231	462	693	924	1155	1386	1617	1848	2079	2310	2541	2772	3003	3234	3465	3696	3927	4158	4389	4620
232	232	464	696	928	1160	1392	1624	1856	2088	2320	2552	2784	3016	3248	3480	3712	3944	4176	4408	4640
233	233	466	699	932	1165	1398	1631	1864	2097	2330	2563	2796	3029	3262	3495	3728	3961	4194	4427	4660

Work /P.U.	Number of Pull-ups executed																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
234	234	468	702	936	1170	1404	1638	1872	2106	2340	2574	2808	3042	3276	3510	3744	3978	4212	4446	4680
235	235	470	705	940	1175	1410	1645	1880	2115	2350	2585	2820	3055	3290	3525	3760	3995	4230	4465	4700
236	236	472	708	944	1180	1416	1652	1888	2124	2360	2596	2832	3068	3304	3540	3776	4012	4248	4484	4720
237	237	474	711	948	1185	1422	1659	1896	2133	2370	2607	2844	3081	3318	3555	3792	4029	4266	4503	4740
238	238	476	714	952	1190	1428	1666	1904	2142	2380	2618	2856	3094	3332	3570	3808	4046	4284	4522	4760
239	239	478	717	956	1195	1434	1673	1912	2151	2390	2629	2868	3107	3346	3585	3824	4063	4302	4541	4780
240	240	480	720	960	1200	1440	1680	1920	2160	2400	2640	2880	3120	3360	3600	3840	4080	4320	4560	4800
241	241	482	723	964	1205	1446	1687	1928	2169	2410	2651	2892	3133	3374	3615	3856	4097	4338	4579	4820
242	242	484	726	968	1210	1452	1694	1936	2178	2420	2662	2904	3146	3388	3630	3872	4114	4356	4598	4840
243	243	486	729	972	1215	1458	1701	1944	2187	2430	2673	2916	3159	3402	3645	3888	4131	4374	4617	4860
244	244	488	732	976	1220	1464	1708	1952	2196	2440	2684	2928	3172	3416	3660	3904	4148	4392	4636	4880
245	245	490	735	980	1225	1470	1715	1960	2205	2450	2695	2940	3185	3430	3675	3920	4165	4410	4655	4900
246	246	492	738	984	1230	1476	1722	1968	2214	2460	2706	2952	3198	3444	3690	3936	4182	4428	4674	4920
247	247	494	741	988	1235	1482	1729	1976	2223	2470	2717	2964	3211	3458	3705	3952	4199	4446	4693	4940
248	248	496	744	992	1240	1488	1736	1984	2232	2480	2728	2976	3224	3472	3720	3968	4216	4464	4712	4960
249	249	498	747	996	1245	1494	1743	1992	2241	2490	2739	2988	3237	3486	3735	3984	4233	4482	4731	4980
250	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000
251	251	502	753	1004	1255	1506	1757	2008	2259	2510	2761	3012	3263	3514	3765	4016	4267	4518	4769	5020
252	252	504	756	1008	1260	1512	1764	2016	2268	2520	2772	3024	3276	3528	3780	4032	4284	4536	4788	5040
253	253	506	759	1012	1265	1518	1771	2024	2277	2530	2783	3036	3289	3542	3795	4048	4301	4554	4807	5060
254	254	508	762	1016	1270	1524	1778	2032	2286	2540	2794	3048	3302	3556	3810	4064	4318	4572	4826	5080
255	255	510	765	1020	1275	1530	1785	2040	2295	2550	2805	3060	3315	3570	3825	4080	4335	4590	4845	5100
256	256	512	768	1024	1280	1536	1792	2048	2304	2560	2816	3072	3328	3584	3840	4096	4352	4608	4864	5120
257	257	514	771	1028	1285	1542	1799	2056	2313	2570	2827	3084	3341	3598	3855	4112	4369	4626	4883	5140
258	258	516	774	1032	1290	1548	1806	2064	2322	2580	2838	3096	3354	3612	3870	4128	4386	4644	4902	5160
259	259	518	777	1036	1295	1554	1813	2072	2331	2590	2849	3108	3367	3626	3885	4144	4403	4662	4921	5180
260	260	520	780	1040	1300	1560	1820	2080	2340	2600	2860	3120	3380	3640	3900	4160	4420	4680	4940	5200
261	261	522	783	1044	1305	1566	1827	2088	2349	2610	2871	3132	3393	3654	3915	4176	4437	4698	4959	5220
262	262	524	786	1048	1310	1572	1834	2096	2358	2620	2882	3144	3406	3668	3930	4192	4454	4716	4978	5240
263	263	526	789	1052	1315	1578	1841	2104	2367	2630	2893	3156	3419	3682	3945	4208	4471	4734	4997	5260
264	264	528	792	1056	1320	1584	1848	2112	2376	2640	2904	3168	3432	3696	3960	4224	4488	4752	5016	5280
265	265	530	795	1060	1325	1590	1855	2120	2385	2650	2915	3180	3445	3710	3975	4240	4505	4770	5035	5300
266	266	532	798	1064	1330	1596	1862	2128	2394	2660	2926	3192	3458	3724	3990	4256	4522	4788	5054	5320
267	267	534	801	1068	1335	1602	1869	2136	2403	2670	2937	3204	3471	3738	4005	4272	4539	4806	5073	5340
268	268	536	804	1072	1340	1608	1876	2144	2412	2680	2948	3216	3484	3752	4020	4288	4556	4824	5092	5360
269	269	538	807	1076	1345	1614	1883	2152	2421	2690	2959	3228	3497	3766	4035	4304	4573	4842	5111	5380
270	270	540	810	1080	1350	1620	1890	2160	2430	2700	2970	3240	3510	3780	4050	4320	4590	4860	5130	5400
271	271	542	813	1084	1355	1626	1897	2168	2439	2710	2981	3252	3523	3794	4065	4336	4607	4878	5149	5420
272	272	544	816	1088	1360	1632	1904	2176	2448	2720	2992	3264	3536	3808	4080	4352	4624	4896	5168	5440
273	273	546	819	1092	1365	1638	1911	2184	2457	2730	3003	3276	3549	3822	4095	4368	4641	4914	5187	5460
274	274	548	822	1096	1370	1644	1918	2192	2466	2740	3014	3288	3562	3836	4110	4384	4658	4932	5206	5480
275	275	550	825	1100	1375	1650	1925	2200	2475	2750	3025	3300	3575	3850	4125	4400	4675	4950	5225	5500
276	276	552	828	1104	1380	1656	1932	2208	2484	2760	3036	3312	3588	3864	4140	4416	4692	4968	5244	5520
277	277	554	831	1108	1385	1662	1939	2216	2493	2770	3047	3324	3601	3878	4155	4432	4709	4986	5263	5540
278	278	556	834	1112	1390	1668	1946	2224	2502	2780	3058	3336	3614	3892	4170	4448	4726	5004	5282	5560
279	279	558	837	1116	1395	1674	1953	2232	2511	2790	3069	3348	3627	3906	4185	4464	4743	5022	5301	5580

Work /P.U.	Number of Pull-ups executed																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
280	280	560	840	1120	1400	1680	1960	2240	2520	2800	3080	3360	3640	3920	4200	4480	4760	5040	5320	5600
281	281	562	843	1124	1405	1686	1967	2248	2529	2810	3091	3372	3653	3934	4215	4496	4777	5058	5339	5620
282	282	564	846	1128	1410	1692	1974	2256	2538	2820	3102	3384	3666	3948	4230	4512	4794	5076	5358	5640
283	283	566	849	1132	1415	1698	1981	2264	2547	2830	3113	3396	3679	3962	4245	4528	4811	5094	5377	5660
284	284	568	852	1136	1420	1704	1988	2272	2556	2840	3124	3408	3692	3976	4260	4544	4828	5112	5396	5680
285	285	570	855	1140	1425	1710	1995	2280	2565	2850	3135	3420	3705	3990	4275	4560	4845	5130	5415	5700
286	286	572	858	1144	1430	1716	2002	2288	2574	2860	3146	3432	3718	4004	4290	4576	4862	5148	5434	5720
287	287	574	861	1148	1435	1722	2009	2296	2583	2870	3157	3444	3731	4018	4305	4592	4879	5166	5453	5740
288	288	576	864	1152	1440	1728	2016	2304	2592	2880	3168	3456	3744	4032	4320	4608	4896	5184	5472	5760
289	289	578	867	1156	1445	1734	2023	2312	2601	2890	3179	3468	3757	4046	4335	4624	4913	5202	5491	5780
290	290	580	870	1160	1450	1740	2030	2320	2610	2900	3190	3480	3770	4060	4350	4640	4930	5220	5510	5800
291	291	582	873	1164	1455	1746	2037	2328	2619	2910	3201	3492	3783	4074	4365	4656	4947	5238	5529	5820
292	292	584	876	1168	1460	1752	2044	2336	2628	2920	3212	3504	3796	4088	4380	4672	4964	5256	5548	5840
293	293	586	879	1172	1465	1758	2051	2344	2637	2930	3223	3516	3809	4102	4395	4688	4981	5274	5567	5860
294	294	588	882	1176	1470	1764	2058	2352	2646	2940	3234	3528	3822	4116	4410	4704	4998	5292	5586	5880
295	295	590	885	1180	1475	1770	2065	2360	2655	2950	3245	3540	3835	4130	4425	4720	5015	5310	5605	5900
296	296	592	888	1184	1480	1776	2072	2368	2664	2960	3256	3552	3848	4144	4440	4736	5032	5328	5624	5920
297	297	594	891	1188	1485	1782	2079	2376	2673	2970	3267	3564	3861	4158	4455	4752	5049	5346	5643	5940
298	298	596	894	1192	1490	1788	2086	2384	2682	2980	3278	3576	3874	4172	4470	4768	5066	5364	5662	5960
299	299	598	897	1196	1495	1794	2093	2392	2691	2990	3289	3588	3887	4186	4485	4784	5083	5382	5681	5980
300	300	600	900	1200	1500	1800	2100	2400	2700	3000	3300	3600	3900	4200	4500	4800	5100	5400	5700	6000
301	301	602	903	1204	1505	1806	2107	2408	2709	3010	3311	3612	3913	4214	4515	4816	5117	5418	5719	6020
302	302	604	906	1208	1510	1812	2114	2416	2718	3020	3322	3624	3926	4228	4530	4832	5134	5436	5738	6040
303	303	606	909	1212	1515	1818	2121	2424	2727	3030	3333	3636	3939	4242	4545	4848	5151	5454	5757	6060
304	304	608	912	1216	1520	1824	2128	2432	2736	3040	3344	3648	3952	4256	4560	4864	5168	5472	5776	6080
305	305	610	915	1220	1525	1830	2135	2440	2745	3050	3355	3660	3965	4270	4575	4880	5185	5490	5795	6100
306	306	612	918	1224	1530	1836	2142	2448	2754	3060	3366	3672	3978	4284	4590	4896	5202	5508	5814	6120
307	307	614	921	1228	1535	1842	2149	2456	2763	3070	3377	3684	3991	4298	4605	4912	5219	5526	5833	6140
308	308	616	924	1232	1540	1848	2156	2464	2772	3080	3388	3696	4004	4312	4620	4928	5236	5544	5852	6160
309	309	618	927	1236	1545	1854	2163	2472	2781	3090	3399	3708	4017	4326	4635	4944	5253	5562	5871	6180
310	310	620	930	1240	1550	1860	2170	2480	2790	3100	3410	3720	4030	4340	4650	4960	5270	5580	5890	6200
311	311	622	933	1244	1555	1866	2177	2488	2799	3110	3421	3732	4043	4354	4665	4976	5287	5598	5909	6220
312	312	624	936	1248	1560	1872	2184	2496	2808	3120	3432	3744	4056	4368	4680	4992	5304	5616	5928	6240
313	313	626	939	1252	1565	1878	2191	2504	2817	3130	3443	3756	4069	4382	4695	5008	5321	5634	5947	6260
314	314	628	942	1256	1570	1884	2198	2512	2826	3140	3454	3768	4082	4396	4710	5024	5338	5652	5966	6280
315	315	630	945	1260	1575	1890	2205	2520	2835	3150	3465	3780	4095	4410	4725	5040	5355	5670	5985	6300
316	316	632	948	1264	1580	1896	2212	2528	2844	3160	3476	3792	4108	4424	4740	5056	5372	5688	6004	6320
317	317	634	951	1268	1585	1902	2219	2536	2853	3170	3487	3804	4121	4438	4755	5072	5389	5706	6023	6340
318	318	636	954	1272	1590	1908	2226	2544	2862	3180	3498	3816	4134	4452	4770	5088	5406	5724	6042	6360
319	319	638	957	1276	1595	1914	2233	2552	2871	3190	3509	3828	4147	4466	4785	5104	5423	5742	6061	6380
320	320	640	960	1280	1600	1920	2240	2560	2880	3200	3520	3840	4160	4480	4800	5120	5440	5760	6080	6400
321	321	642	963	1284	1605	1926	2247	2568	2889	3210	3531	3852	4173	4494	4815	5136	5457	5778	6099	6420
322	322	644	966	1288	1610	1932	2254	2576	2898	3220	3542	3864	4186	4508	4830	5152	5474	5796	6118	6440
323	323	646	969	1292	1615	1938	2261	2584	2907	3230	3553	3876	4199	4522	4845	5168	5491	5814	6137	6460
324	324	648	972	1296	1620	1944	2268	2592	2916	3240	3564	3888	4212	4536	4860	5184	5508	5832	6156	6480
325	325	650	975	1300	1625	1950	2275	2600	2925	3250	3575	3900	4225	4550	4875	5200	5525	5850	6175	6500

Work /P.U.	Number of Pull-ups executed																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
326	326	652	978	1304	1630	1956	2282	2608	2934	3260	3586	3912	4238	4564	4890	5216	5542	5868	6194	6520
327	327	654	981	1308	1635	1962	2289	2616	2943	3270	3597	3924	4251	4578	4905	5232	5559	5886	6213	6540
328	328	656	984	1312	1640	1968	2296	2624	2952	3280	3608	3936	4264	4592	4920	5248	5576	5904	6232	6560
329	329	658	987	1316	1645	1974	2303	2632	2961	3290	3619	3948	4277	4606	4935	5264	5593	5922	6251	6580
330	330	660	990	1320	1650	1980	2310	2640	2970	3300	3630	3960	4290	4620	4950	5280	5610	5940	6270	6600
331	331	662	993	1324	1655	1986	2317	2648	2979	3310	3641	3972	4303	4634	4965	5296	5627	5958	6289	6620
332	332	664	996	1328	1660	1992	2324	2656	2988	3320	3652	3984	4316	4648	4980	5312	5644	5976	6308	6640
333	333	666	999	1332	1665	1998	2331	2664	2997	3330	3663	3996	4329	4662	4995	5328	5661	5994	6327	6660

Appendix D-3. Score for Total Work Done with Pull-ups

Total Work	Score	Total Work	Score	Total Work	Score	Total Work	Score
0	0	312.5	25	1100	50	2600	75
12.5	1	325	26	1160	51	2660	76
25	2	337.5	27	1220	52	2720	77
37.5	3	350	28	1280	53	2780	78
50	4	362.5	29	1340	54	2840	79
62.5	5	375	30	1400	55	2900	80
75	6	387.5	31	1460	56	2960	81
87.5	7	400	32	1520	57	3020	82
100	8	412.5	33	1580	58	3080	83
112.5	9	425	34	1640	59	3140	84
125	10	437.5	35	1700	60	3200	85
137.5	11	450	36	1760	61	3260	86
150	12	462.5	37	1820	62	3320	87
162.5	13	475	38	1880	63	3380	88
175	14	487.5	39	1940	64	3440	89
187.5	15	500	40	2000	65	3500	90
200	16	560	41	2060	66	3560	91
212.5	17	620	42	2120	67	3620	92
225	18	680	43	2180	68	3680	93
237.5	19	740	44	2240	69	3740	94
250	20	800	45	2300	70	3800	95
262.5	21	860	46	2360	71	3860	96
275	22	920	47	2420	72	3920	97
287.5	23	980	48	2480	73	3980	98
300	24	1040	49	2540	74	4040	99
						4100	100

APPENDIX E. U.S. ARMY PUSH-UP SCORING STANDARDS

No.PushUp Repititions	Male Age Group								Female Age Group							
	17-21	22-26	27-31	32-36	37-41	42-46	47-51	52+	17-21	22-26	27-31	32-36	37-41	42-46	47-51	52+
82	100															
81	99															
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69	87	89	91	96	97											
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26	44	46	48	53	54	60	64	70	68	70	72	74	78	81	85	86
25	43	45	47	52	53	59	63	69	67	69	71	73	77	80	84	85
24	42	44	46	51	52	58	62	68	66	68	70	72	76	79	83	84
23	41	43	45	50	51	57	61	67	65	67	69	71	75	78	82	83
22	40	42	44	48	50	56	60	66	64	66	68	70	74	77	81	82
21	39	41	42	46	48	55	58	65	63	65	67	69	73	76	80	81
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19	37	38	38	42	44	52	54	63	61	63	65	67	71	74	78	79
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17	34	34	34	38	40	48	50	61	58	61	63	65	68	70	76	77
16	32	32	32	36	38	46	48	60	56	60	62	64	66	68	75	76
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14	28	28	28	32	34	42	44	54	52	56	58	60	62	64	72	74
13	26	26	26	30	32	39	43	51	50	54	56	58	60	62	70	72
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11	22	22	22	26	28	33	38	44	44	50	52	54	56	58	64	68
10	20	20	20	24	26	30	36	40	40	46	50	52	54	56	60	64
9	18	18	18	22	24	27	34	36	36	42	45	50	52	54	57	60
8	16	16	16	20	22	24	32	32	32	38	40	45	50	52	54	56
7	14	14	14	18	20	21	28	28	28	34	35	40	44	50	51	52
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4	8	8	8	12	12	12	16	16	16	20	20	24	26	29	32	32
3	6	6	6	9	9	9	12	12	12	15	15	18	20	22	24	24
2	4	4	4	6	6	6	8	8	8	10	10	12	14	15	16	16
1	2	2	2	3	3	3	4	4	4	5	5	6	7	8	8	8

APPENDIX F. PILOT STUDY SURVEY RESULTS (UNPUBLISHED)

Pilot-Study Questionnaire:

17.9%	Polled indicated being over their maximum weight requirement at some time during the course of the year.
26.9%	Have to make an effort (extra exercise and/or diet) to make weight for PFT's.
28.7%	Do not feel the current weight standards are fair/valid for all male Marines.
59.6%	Indicated the weight standards need to be adjusted to account for today's lifestyles/eating habits/work-out requirements.
51.6%	Felt the weight standards should compensate for age.
19.3%	Do not feel the current 18% body fat standard is fair/valid for all male Marines.
43.5%	Indicated the % body fat standards need to be adjusted to account for today's lifestyles/eating habits/work-out requirements.
51.6%	Felt the % body fat standards should compensate for age.
31.8%	Do not feel the dead-hang pull-up requirements are a fair predictor of their physical strength/fitness.
32.3%	Do not think the dead-hang pull-up is a fair/valid test for all male Marines.
61.9%	Indicated the points allotted for dead-hang pull-ups should be adjusted in order to be more equal to the distribution of points for the run and sit-up events.
66.4%	Felt the PFT standards should compensate for age.

APPENDIX G. GLOSSARY OF ACRONYMS

ALMAR	All Marine Message
AR	Army Regulation
BF	Body Fat
CCC	Combat Conditioning Course
CmbtRun	Combat Run
DoD	Department of Defense
End'crs	Endurance course
F and M	Fire and Maneuver
GLM	Generalized Linear Model
MCO	Marine Corps Order
MOS	Military Occupation Specialty
NCHS	National Center for Health Statistics
Nm	Newton mass
O'crs	Obstacle course
OCS	Officer Candidate School
PFT	Physical Fitness Test
pBF	Percent Body-Fat
PU	Pull-up
SD	Standard Deviation
SU	Sit-up
T&E Div	Training and Education Division

APPENDIX H. REGRESSION DIAGNOSTIC PLOTS

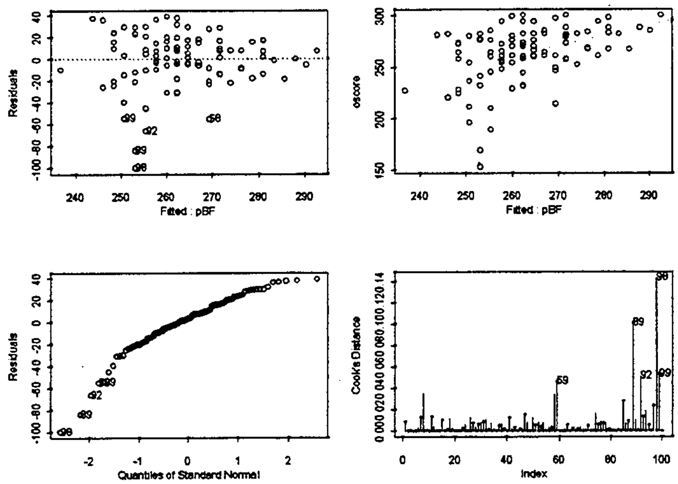

Figure H-1. Modified PFT Scores Regressed on Percent Body-Fat (over 26 years old, N = 100).

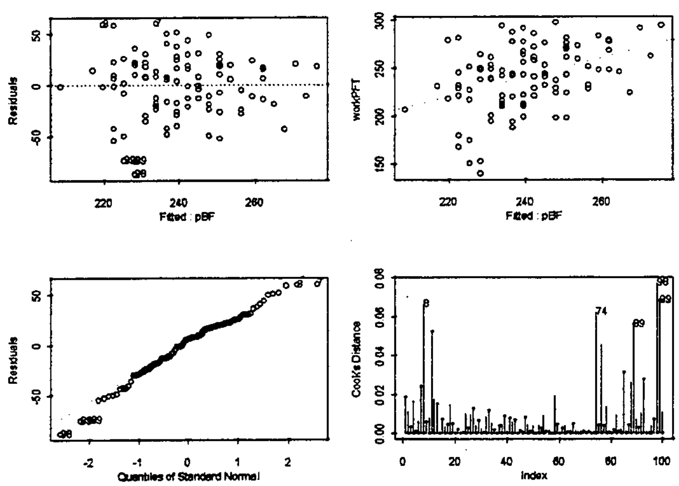

Figure H-2. Proposed PFT Scores Regressed on Percent Body-Fat (over 26 years old, N = 100).

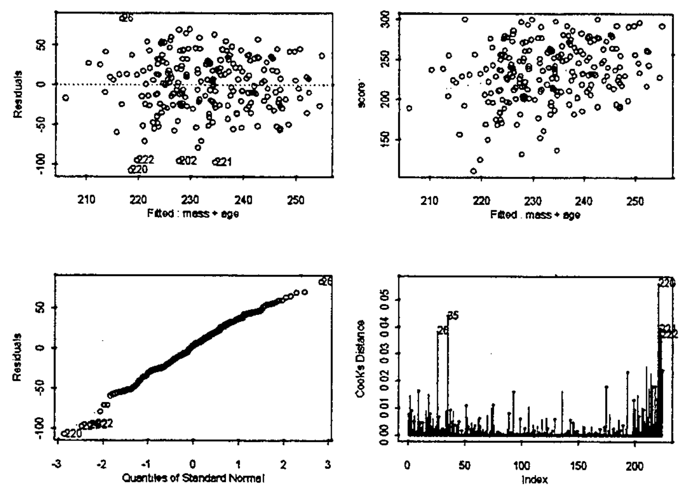

Figure H-3. PFT Scores Regressed on Body Mass and Age (all ages, N = 223).

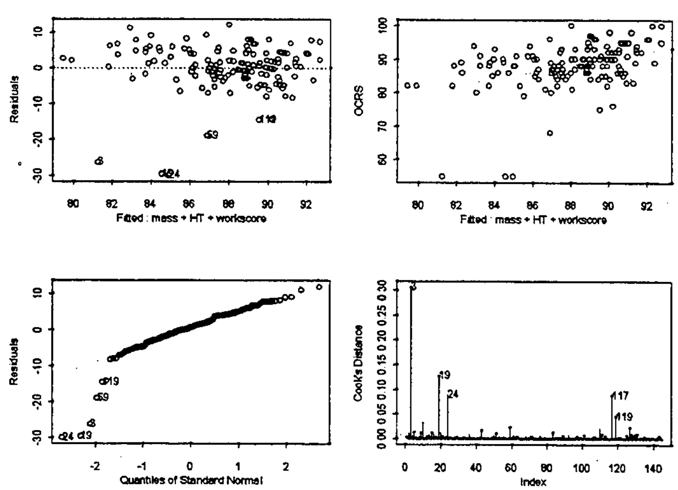

Figure H-4. Obstacle Course Scores Regressed on Work (for pull-ups), height, and mass (N = 144).

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